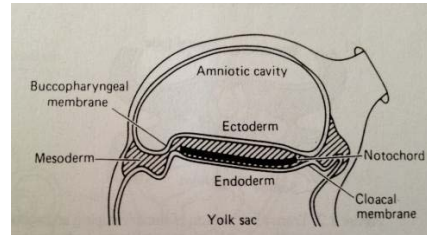


Embryology of Ear

- Prenatal development divided in to separate periods:

1. First period (Pre-embryonic):

- From implantation to end of 3rd week.
- Three layers develop (ectoderm, mesoderm & endoderm) containing the notochord.



2. Second period (Embryonic):

- 35 days (until the end of 8th week)
- Major systems and organs are formed, embryo has external shape that recognizable as human.
- Mesoderm give raise to Pharyngeal arches.
- Ectoderm around the notochord give raise to the Neural crest

3. Fetal period:

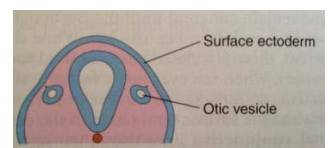
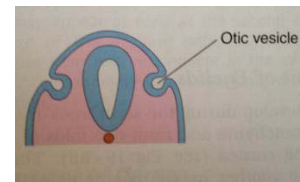
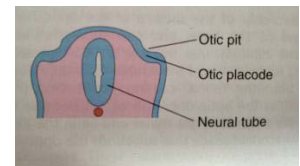
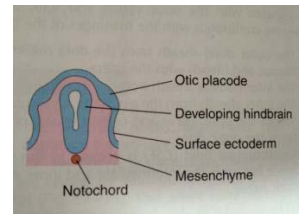
- Remaining 7 months
- Change of position and shape of structure

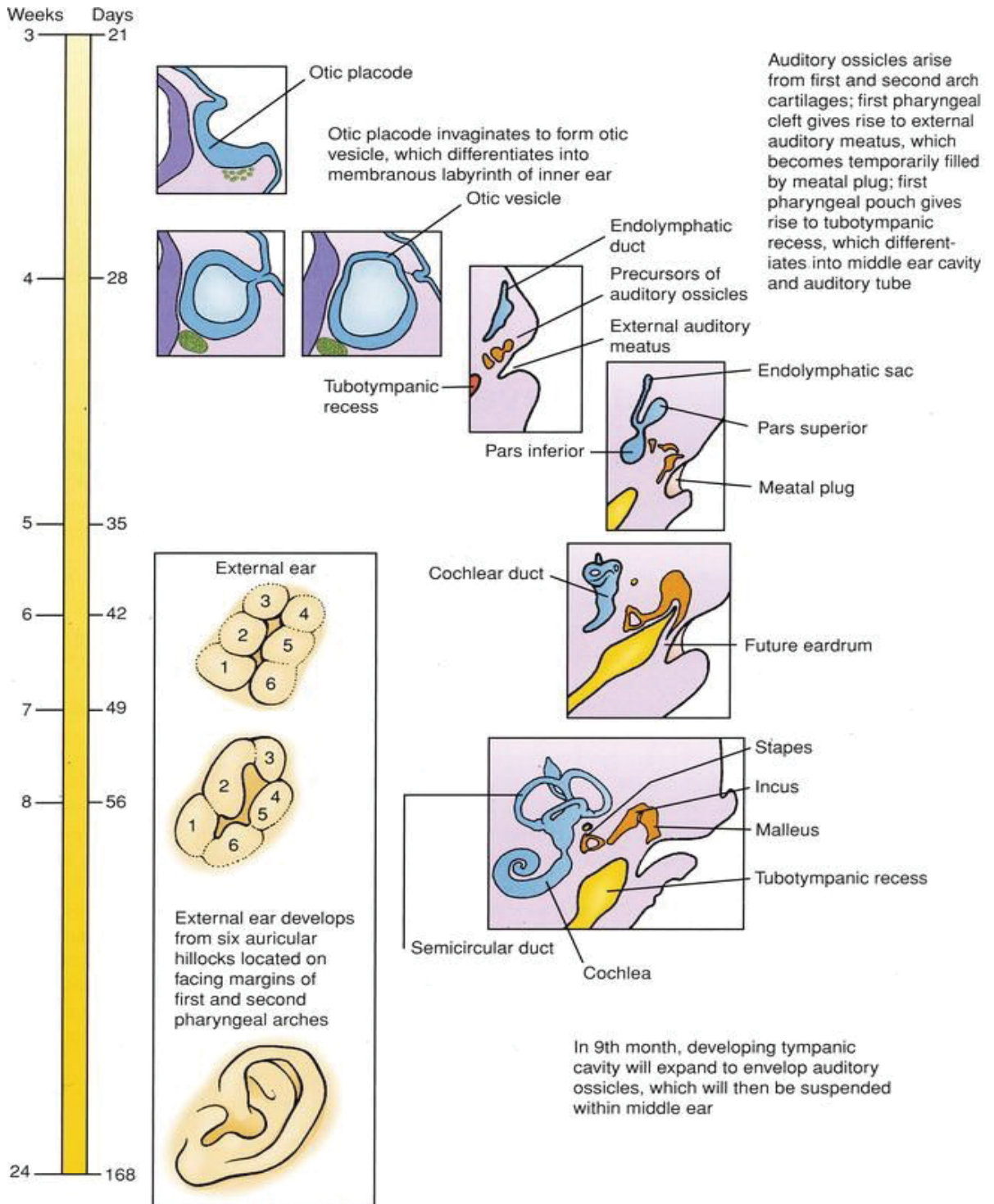
Development of Ear

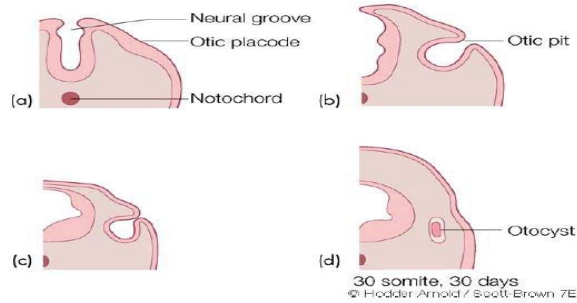
- Composed of 3 anatomical parts:
 1. External ear: (auricle, EAC and tympanic membrane)
 2. Middle ear
 3. Internal ear

Development of INNER EAR:

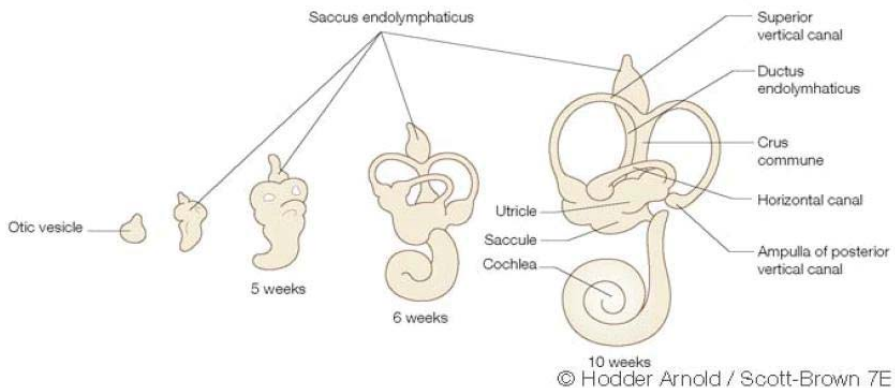
- 1st to develop from the 3 parts.
- Starts in 3rd-4th week of fetal life
- Complete by the 16th week.
- By 4th week:
 - Thickening of surface Ectoderm (**Otic Placode**) on each side of caudal part of hindbrain (myelencephalon)
 - Its form is stimulated by notochord and paraxial mesoderm
 - It invaginates and sinks deep into the underlying mesenchyme to form (**Otic Pit**)
 - Edges of otic pit comes together to form (**Otic Vesicle or Otocyst**) which is considered as (**Primordium of membranous labyrinth**)
 - Otic vesicle loses its connection with surface ectoderm.







- A diverticulum grows from the otic vesicle and elongates to form **Endolymphatic duct and sac (1st to develop)**
- Otocyst is differentiated into 2 parts:
 - 1. Dorsal Utriclar part:**
 - Endolymphatic duct, utricle & semicircular ducts)
 - 2. Ventral Saccular part:**
 - Saccule & cochlear duct



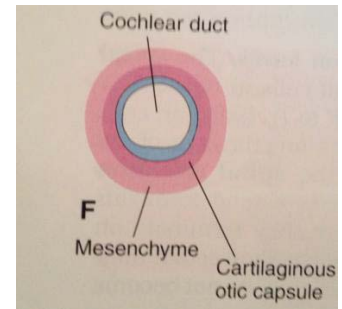
Development of Utricular part of membranous labyrinth takes place **Earlier** than Sacular part.

- From the Dorsal utricular part:
- 3 dislike diverticula grows out from the utricular part, the central parts of these diverticula fuse and disappear (**Semicircular Ducts**)
- Attached to the utricle, later enclosed in **semicircular canals** of **bony labyrinth** (from mesenchyme around otic vesicle)
- At one end of each semicircular duct a dilatation **Ampullae**, inside it differentiate the specialized receptors area (**cristae ampullares**)
- In the utricle and saccule (**maculae**)

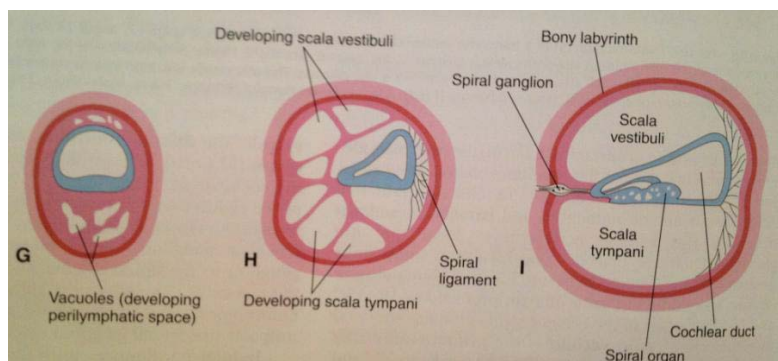
- From the ventral saccular part:
- Tubular diverticulum grows (**Cochlear duct**) and coils to form the **membranous cochlea**
- Saccule connected with cochlea by **Ductus reuniens (narrowest segment)**
- **Organ of corti** (Spiral organ) differentiate from cells in the wall of cochlear duct
- Ganglion cells of the 8th nerve migrate along the coils of membranous cochlea and form **spiral ganglion**
- Nerve processes extend from this ganglion to the spiral organ and terminate on the hair cells
- **Periotic Duct: within the cochlear aquaduct**, connects the scala tympani to the posterior cranial fossa

Bony labyrinth:

- Mesenchyme around the otic vesicle condenses and differentiates into Cartilaginous (**Otic Capsule**)
- Transforming growth factor-B1 may play role
- As the membranous labyrinth enlarges, vacuoles appear in the otic capsule which soon coalesce to form **perilymphatic space**
- Membranous labyrinth become suspended in perilymph



- The perilymphatic space related to cochlea develops two divisions:
 1. **Scala Vestibuli**
 2. **Scala Tympani**



- Cartilaginous otic capsule later ossifies to form the **bony labyrinth** (**Start ossification at 16 weeks**)

- Variable number of centers that finally fuse without leaving telltale suture lines. (From periosteal and endochondral ossification)
- The dense bony mass is the Petrous bone
- **INNER ear reach Adult SHAPE (NOT SIZE) by the middle of the fetal period (20-22 weeks)**
- **Cochlea is developed sufficiently by 20 weeks of gestation and the fetus can hear in the womb of the mother.**
- Channels within the otic capsule includes **oval window** where **part of the otic capsule becomes the stapes footplate and the annular ligament**, thereby allowing sound from the middle ear to enter the labyrinthine fluids

Table 225.4 Development of communication channels passing through labyrinth.

	Channel
Internal auditory meatus	Persisting channel in cartilage model around VII and VIII nerves
Subarcuate fossa	Persisting vascular channel
Vestibular aqueduct	Fifth and sixth ossification centres fuse around the endolymphatic duct
Cochlear aqueduct	Resorption of precartilag
Fossula ante fenestram	Resorption of precartilag
Fossula post fenestram (inconstant)	Resorption of cartilage
Oval window	Otic capsule becomes footplate of stapes and annular ligament
Round window	Persisting cartilage becomes round window niche and membrane

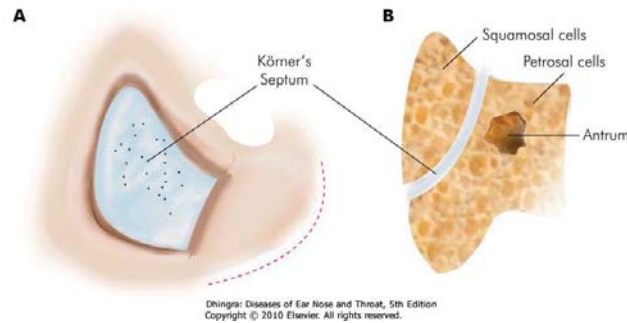
Development of External and Middle ear:

- External and middle ears are **independent** of the development of inner ear
- We can see malformed and non-functional inner ear in the presence of normal external and middle ears, and vice versa.
- External and middle ears mainly derived from **1st and 2nd Pharyngeal ARCHES.**

Pharyngeal Arch	Nerve	Muscles	Skeleton
1. Mandibular	V. Trigeminal: mandibular divisions	Mastication (temporal; masseter; medial, lateral pterygoids); mylohyoid; anterior belly of digastric; tensor palatine, tensor tympani	Premaxilla, maxilla, zygomatic bone, part of temporal bone, Meckel's cartilage, mandible, malleus, incus, anterior ligament of malleus, sphenomandibular ligament
2. Hyoid	VII. Facial	Facial expression (buccinator; auricularis; frontalis; platysma etc); posterior belly of digastric; stylohyoid; stapedius	Stapes; styloid process; stylohyoid ligament; lesser horn and upper portion of body of hyoid bone

Development of Middle ear:

- **Tubotympanic Recess** from the Endoderm of **1st Pharyngeal POUCH.**
- 1. Proximal part form **Eustachian tube**
- 2. Distal part become **Tympanic cavity** (which envelop the ossicles, their tendons, ligament and corda typani)
- Late fetal period, expansion of tympanic cavity gives rise to **mastoid antrum** (in the petromastoid part of the temporal bone)
- **Middle ear reaches Adult SHAPE at Birth.**
- **No Mastoid air cells present at Birth.**
- **Mastoid** develops from the Squamous and Petrous bones.
- Petrosquamosal suture may persist as a bony plate (**Korner's septum**) separating superficial squamosal cells from the deep petrosal cells.
- **By 2-3 years of age the mastoid cells are well developed and produce conical projections of the temporal bone (mastoid process)**



Pharyngeal Arch	Nerve	Muscles	Skeleton
1. Mandibular	V. Trigeminal: mandibular divisions	Mastication (temporal; masseter; medial, lateral pterygoids); mylohyoid; anterior belly of digastric; tensor palatine, tensor tympani	Premaxilla, maxilla, zygomatic bone, part of temporal bone, Meckel's cartilage , mandible, malleus, incus, anterior ligament of malleus, sphenomandibular ligament
2. Hyoid	VII. Facial	Facial expression (buccinator; auricularis; frontalis; platysma etc); posterior belly of digastric; stylohyoid; stapedius	Stapes; styloid process; stylohyoid ligament; lesser horn and upper portion of body of hyoid bone

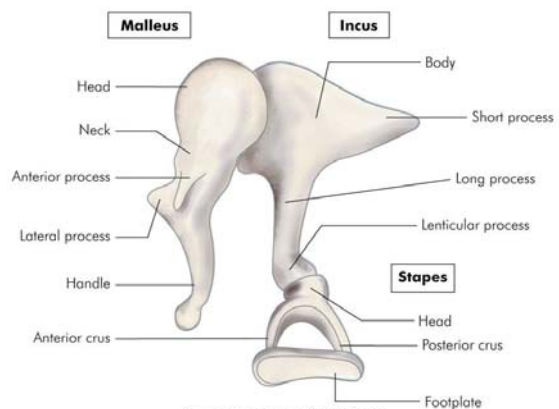
- Ossicles, muscles and nerves in the table above

1. First Branchial Arch (Meckel's cartilage):

- Malleus Head and neck (Mesoderm)
- Anterior Malleal ligament,
- Incus Body and Short process (Mesoderm)

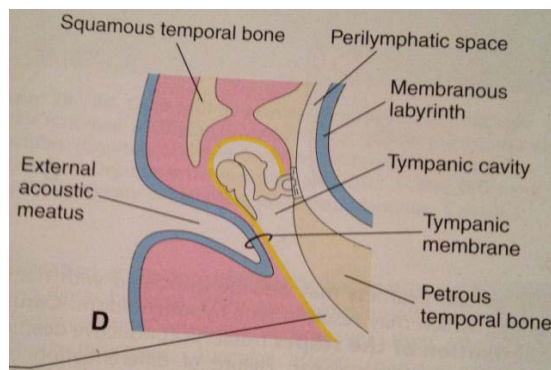
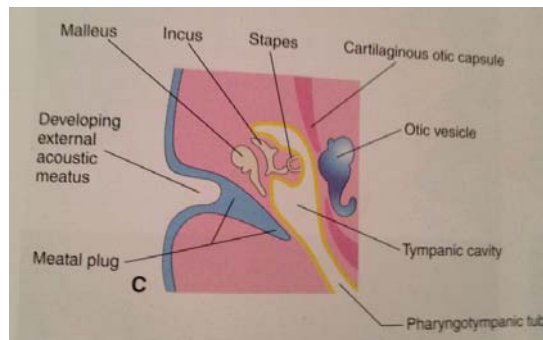
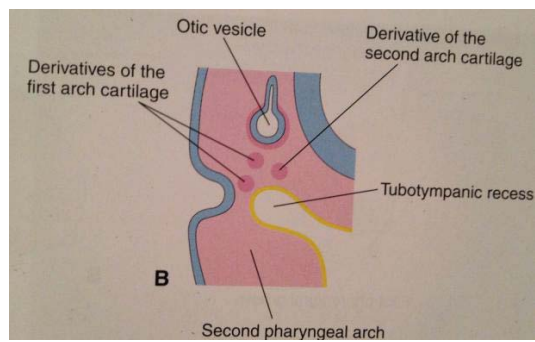
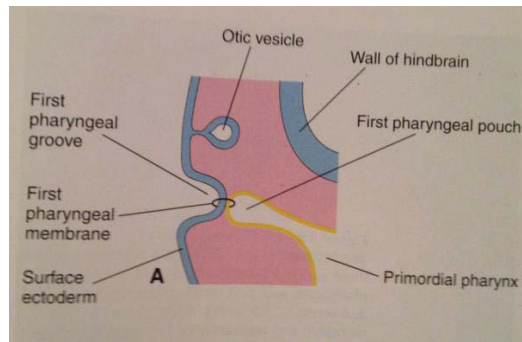
2. Second Branchial Arch (Reichert's cartilage):

- Handle of the Malleus
- Long process and Lenticular process of the incus
- Stapes (except vestibular part of footplate and Annular ligament from Otic capsule)



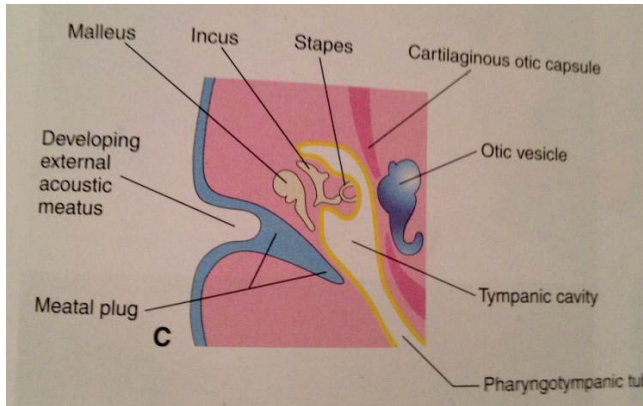
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Figure 1.12 Ear ossicles and their parts.

- Upper parts of ossicles derived from 1st ARCH
- Lower parts of ossicles derived from 2nd ARCH



Development of External Ear:

- **External acoustic meatus** develop from **1st pharyngeal GROOVE**
- Ectodermal cells at the bottom of it proliferate to form a solid epithelial plat (**Meatal plug**)

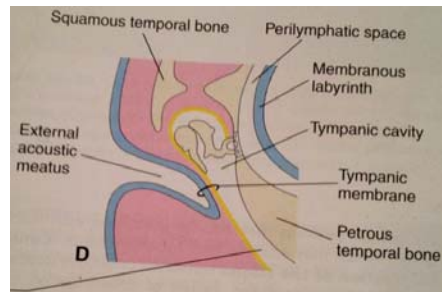


- Late in fetal period central part of the plug degenerate forming a cavity that becomes the internal part of the external acoustic meatus

Degeneration of Plug starts at **7th month** from Medial to Lateral

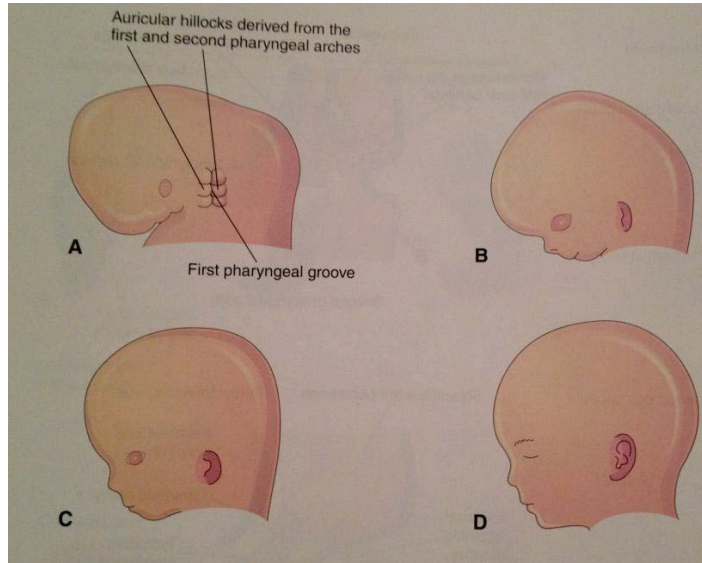
Failure of recannulization results in aural atresia, and may be normal boney but atresia in cartilage only - Canal cholesteatoma

- The meatus short at birth
 - **EAC reach Adult LENGTH by 9th year**
 - **Tympanic membrane** from **1st pharyngeal MEMBRANE** which separate the 1st groove from 1st pouch.
1. Ectoderm of the 1st GROOVE form Squamous outer layer of TM (thin skin)
 2. Mesoderm from 1st & 2nd ARCH form collagenic fibers between the 2 layers.
 3. Endoderm of 1st POUCH form inner mucosal layer (ciliated columnar)



Auricle

- Develops from 6 Mesenchymal proliferations in the **1st & 2nd pharyngeal ARCHES (Auricular hillocks)**
- It surrounds the 1st pharyngeal Groove
- Initially, Auricle begin to develop low in the base of the neck
- As the mandible develop it move to its normal position (more lateral and cranial).



- **Tragus** develops from the **Tubercle of the 1st ARCH**
- **Rest of the pinna** develops from the remaining **5 Tubercles of the 2nd ARCH.**

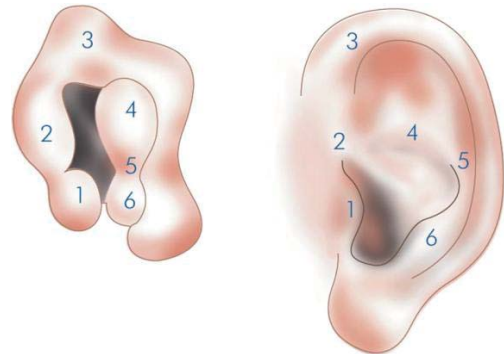
Pasha:

1. First Branchial Arch:

- Hillock 1–3:
- 1. Tragus
- 2. Helical crus
- 3. Helix

2. Second Branchial Arch:

- Hillock 4–6:
- 4. Antihelix crus
- 5. Antihelix
- 6. Lobule and antitragus



- **Ear lobule is the last to develop**

Faulty fusion between 1st and 2nd ARCHs tubercles causes **Preauricular sinus or cyst** which is commonly seen between the tragus and crus of helix.

- By 20th week, Pinna achieves **Adult SHAPE**

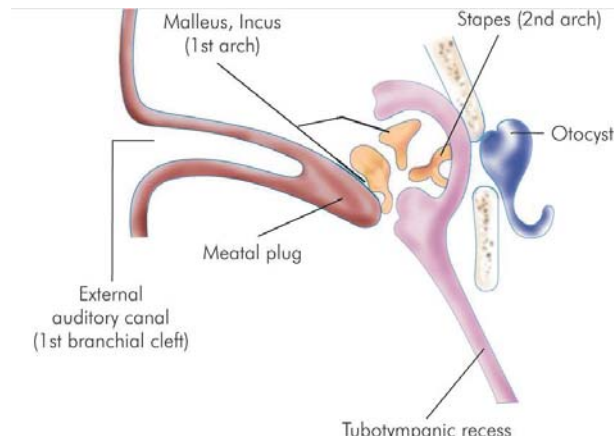


Table 1-3. Timing of development of the ear in the week of gestation*

Development	Pinna	Meatus	Middle ear	Vestibular labyrinth	Cochlea
Begins	6th	8th	3rd	3rd	3rd
Completes	20th	28th	30th	20th	20th

*Source: Gulya, A.J. Developmental Anatomy of the Ear. In Glasscock and Shambaugh ed. Surgery of the Ear. Philadelphia: W.B. Saunders Company, 1990.

Temporal bone:

- Derived from 4 separate morphological elements fuse together
1. Tympanic bone.
 2. Squamous bone.
 3. Petromastoid complex
 4. Styloid process

Some Anomalies

Inner ear:

(i) *Sheibe's dysplasia.*

- Most common inner ear anomaly.
- *Cochleosaccular dysplasia.*
- Dysplasia is seen in the cochlea and saccule.
- Bony labyrinth is NORMAL.
- Superior part of membranous labyrinth (utricle and semicircular ducts) is also NORMAL.
- Inherited as an autosomal recessive non-syndromic trait.

(ii) *Alexander's dysplasia.*

- Affects only the basal turn of membranous cochlea.
- Only high frequencies are affected.
- Residual hearing is present in low frequencies and can be exploited by amplification with hearing aids.

(iii) *Bing-Siebenmann dysplasia.*

- Complete absence of membranous labyrinth.

(iv) *Michel aplasia.*

- Complete absence of bony and membranous labyrinth.
- Petrous apex is absent.
- External and middle ears may be completely unaffected.
- No hearing aids or cochlear implantation can be used.

(v) *Mondini's dysplasia.*

- Only basal coil is present or cochlea is 1.5 turns.
- Absence of osseous spiral lamina.
- Incomplete partition between the scalae
- Unilateral or bilateral.
- May be seen in Pendred, Waardenburg, Branchio-oto-renal, Treacher-Collins and Wildervanch syndromes.

(vi) *Enlarged vestibular aqueduct.*

- Vestibular aqueduct is enlarged (>2 mm)
- Endolymphatic sac is also enlarged and can be seen on T₂ MRI.
- Early onset sensorineural hearing loss, which is progressive.
- Vertigo may be present.
- Perilymphatic fistula may occur.

(vii) *Semicircular canal malformations.*

- Both superior and lateral or only lateral semicircular canal malformations may be seen.
- They can be identified on imaging techniques

External ear:

- Auricular appendages (skin tags)
- Low-set slanted ear
- Absence of auricle
- Microtia
- Preauricular sinus
- Atresia of external acoustic meatus

Middle ear:

- Congenital fixation of stapes

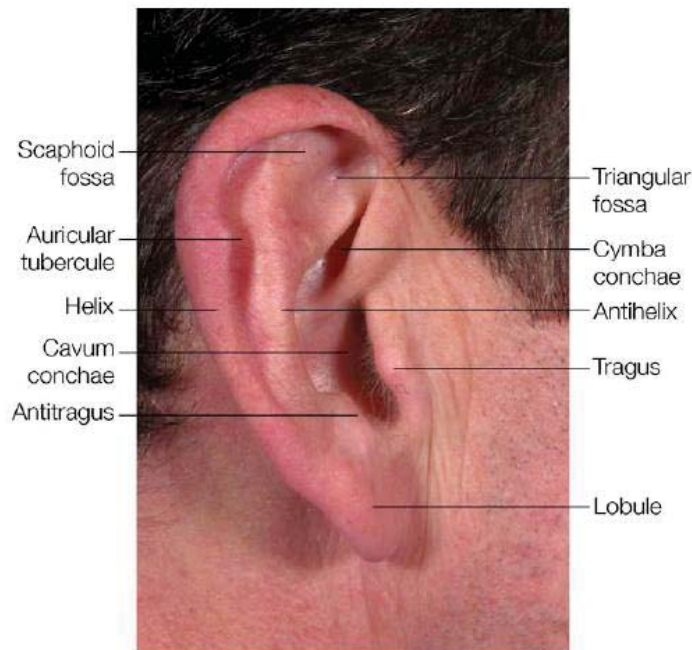
Anatomy of External Ear

- Consists of:

1. Auricle or pinna
2. External acoustic canal
3. Tympanic membrane

1. Auricle or Pinna:

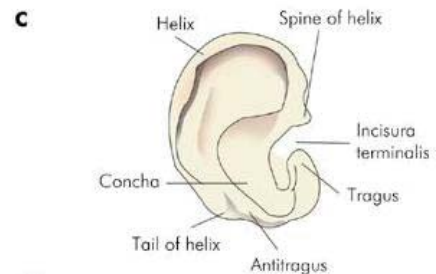
- Projects at a variable angle from the side of the head
- External ear is less than 2-3 cm from the head,
- At an angle of less than 25 degrees from the side of the head.
- Function in collecting sound.
- Lateral surface of the auricle has characteristic prominences and depressions different in every individual even among identical twins.
- This unique pattern is comparable to fingerprints.



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- The medial (cranial) surface of the auricle has elevations corresponding to the depressions on the lateral surface, and possesses corresponding names, for example the eminentia conchae.
- Post-auricular sulcus is the depression behind the ear next to the head

- Auricle is formed from **Elastic fibrocartilage** and is a continuous plate Except for a narrow gap between the tragus and the anterior crus of the helix, where it is replaced by a dense fibrous tissue band (***Incisura terminalis***) which is site for an endaural incision because it will not cut through cartilage.
- Lobule lies below the antitragus and is soft, also composed of fibrous and adipose tissue (no cartilage).
- Cartilage of auricle extends about 8 mm down the ear canal to form its Lateral third of EAC
- Cartilage of the auricle is covered with perichondrium from which it derives its supply of nutrients (**cartilage itself is avascular**).
- Stripping the perichondrium from the cartilage, as occurs following injuries that cause haematoma, can lead to cartilage necrosis and formation of Crumpled up 'boxer's ears' cowlflower ear.
- Skin of the pinna is Thin and closely attached to the perichondrium on the lateral surface
- On the medial (cranial) surface, there is a definite subdermal adipose layer that allows dissection during pinnaplasty surgery.
- Skin of the auricle is covered with **Fine hairs** and, most noticeably in the concha and the scaphoid fossa, there are **sebaceous glands** opening into the root canals of these hairs.
- On the tragus and intertragic notch **coarse, thick hairs** may develop in the middle-aged and older male.



- Extrinsic Ligaments of Auricle:

- Connects Cartilage of the auricle Temporal bone.

1. Anterior ligament:

- From the tragus and from a cartilaginous spine on the anterior rim of the crus of the helix to the root of the zygomatic arch.

2. Posterior ligament:

- From medial surface of the concha to the lateral surface of mastoid prominence.

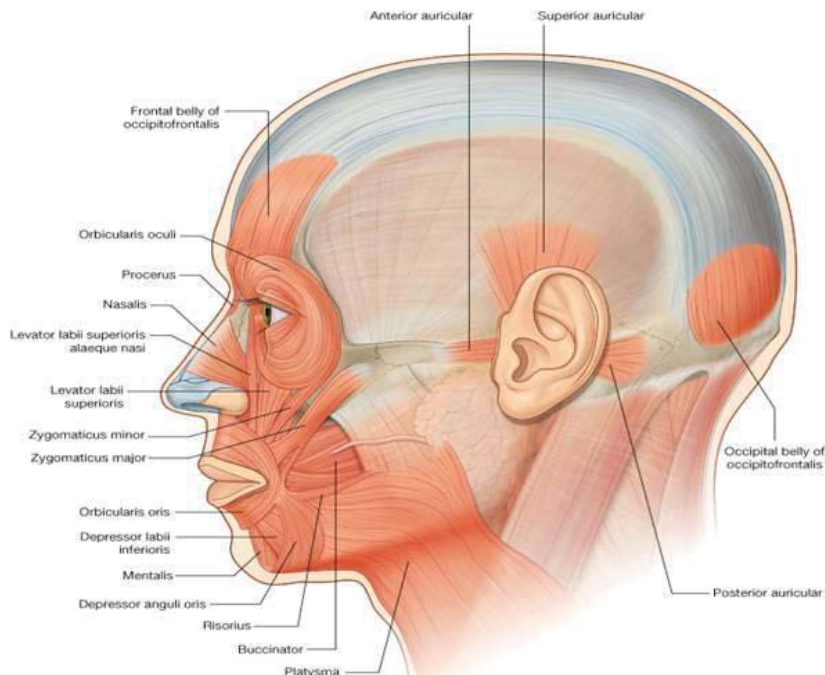
- Intrinsic Ligaments of Auricle:

- Connect various parts of the cartilaginous auricle.
- Connects between helix and tragus and another runs from the antihelix to the posteroinferior portion of the helix.

- Extrinsic Muscles of Auricle:

- 3 muscles radiate out from the auricle to insert into the epicranial aponeurosis.
- Auricularis anterior, superior and posterior.
- Supplied by Facial nerve CN-VII

Muscles of the External Ear				
Auricularis anterior	Epicranial aponeurosis	Auricle	Facial nerve	Small amount of auricular movement in some individuals
Auricularis superior	Epicranial aponeurosis	Auricle	Facial nerve	Small amount of auricular movement in some individuals
Auricularis posterior	Epicranial aponeurosis	Auricle	Facial nerve	Small amount of auricular movement in some individuals



- Intrinsic Muscles of Auricle:
- 6 in number.
- Small, inconsistent and without useful function.

Blood supply for the pinna:

- Branches of External carotid Artery.

1. Posterior auricular Artery:

- The dominant artery.
- Supply:
 - o Medial surface (except the lobule).
 - o Concha
 - o Middle and lower portions of the helix.
 - o Lower part of the antihelix.

2. Anterior Auricular Artery:

- Branch from Superficial Temporal artery.
- Supply:
 - o Upper portions of the helix
 - o Antihelix
 - o Triangular fossa
 - o Tragus
 - o Lobule.

3. Small auricular Artery:

- Branch from Occipital artery.
- Assist the posterior auricular in supplying the medial surface.

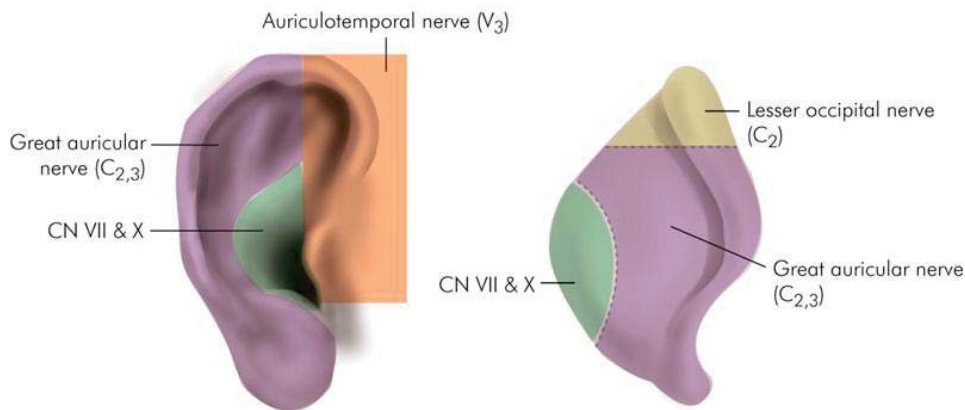
The lymphatic drainage:

- Posterior surface --> Lymph nodes at the mastoid tip
- Tragus and from upper part of the anterior surface to --> Preauricular nodes
- Rest of auricle --> Upper deep cervical nodes.

- Nerves supply of auricle:

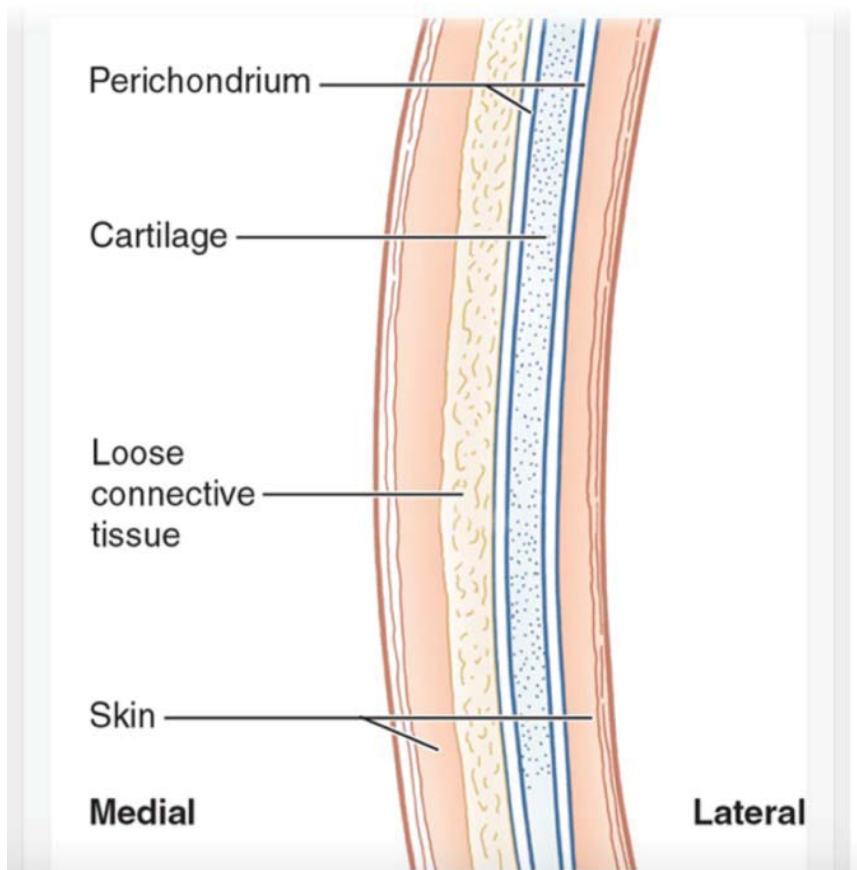
Table 225.1 Sensory innervation of the auricle.

Nerve	Derivation	Region supplied
Greater auricular	Cervical plexus C2, 3	Medial surface and posterior portion of lateral surface
Lesser occipital	Cervical plexus C2, 3	Superior portion of medial surface
Auricular	Vagus X	Concha and antihelix Some supply medial surface (eminetia concha)
Auriculotemporal	Vc mandibular	Tragus, crus of helix and adjacent helix
Facial VII		Probably supplies small region in the root of concha



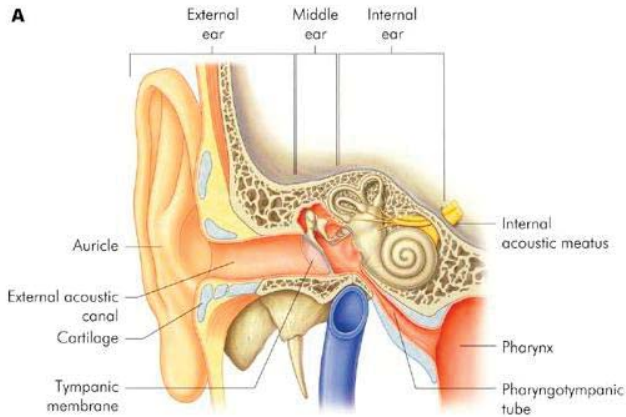
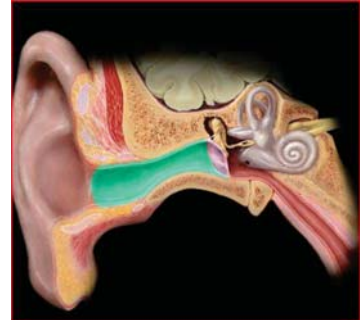
Dhingra: Diseases of Ear Nose and Throat, 5th Edition
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Figure 1.3 Nerve supply of pinna. (A) Lateral surface of pinna. (B) Medial or cranial surface of pinna.

- Pinna can be source of several graft materials for the surgeon.
- Cartilage from the tragus, perichondrium from the tragus or concha, and fat from the lobule are frequently used for reconstructive surgery of the middle ear.
- Conchal cartilage has also been used to correct the depressed nasal bridge while the composite grafts of the skin and cartilage from the pinna are sometimes used for repair of defects of nasal ala.

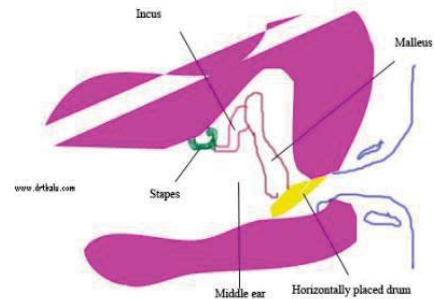


2. External auditory canal

- Extends from Concha of auricle to Tympanic membrane.
- 2.4 cm Long.
- Cartilaginous in Lateral One-third.
- Bony in Medial two-thirds.
- In Adults, it is Not a straight tube.
- Outer part is directed:
- Upwards, backwards and medially
- Inner part is directed:
- Downwards, forwards and medially.
- To examine tympanic membrane, the pinna has to be Pulled upwards, backwards and laterally so as to bring the two parts in alignment.



- **In Neonate,**
- Tympanic portion of temporal bone is not yet developed.
- No bony external meatus
- Tympanic membrane is more horizontally placed.
- Auricle must be gently drawn downwards and backwards for the best view of the tympanic membrane.



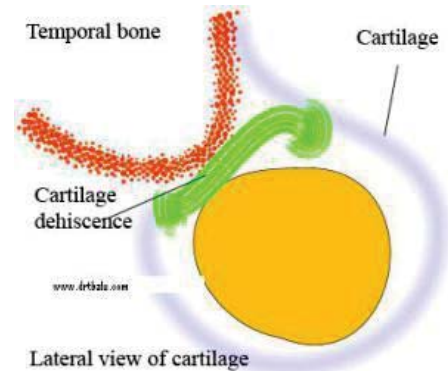
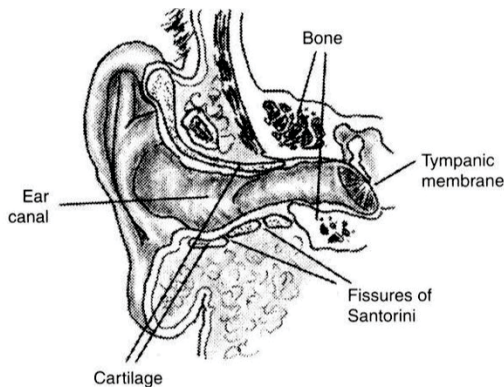
- Antero-inferior wall of EAC is slightly longer (31 mm) than Postero-superior wall (25 mm) because of Antero-inferior inclination of the ear drum.

EAC is divided into two parts:

1. Cartilaginous
2. Bony.

Cartilaginous Part:

- Outer 1/3
- 8 mm long.
- Continuation of pinna cartilage .
- Surrounds by incomplete cylinder of cartilage which is deficient in its superior portion.
- This defect is bridged by dense fibrous tissue that is attached to the Squamous portion of temporal bone.
- Cartilaginous canal is attached to rim of the bony canal by fibrous bands.
- Constriction at junction of the cartilage and bony part (1st constriction)



- Fissures of Santorini:
 - o 2 horizontal fissures located Antero-inferiorly in the cartilaginous portion.
 - o Render more flexibility to the external canal.
 - o Lymphatic channels that connect the lateral cartilaginous EAC to the parotid and glenoid fossa region
 - o Allow infections and tumor to pass between the external canal and the parotid gland.
- Skin covering the cartilaginous canal:
 - o Thick
 - o Contains ceruminous and sebaceous glands.
 - o Contains Hair which is only confined to the outer canal (most numerous at lateral end of the canal, less numerous medially and totally absent from the bony cartiagenous junction).
 - o Furuncles are seen only in outer third.

Bony Part

- Medial 2/3
- 16 mm long
- Composed of a complete cylinder of bone extending laterally from the ear drum.
- Narrower than cartilaginous portion and becomes smaller closer to tympanic membrane.
- Anterior and Inferior walls:
 - o Tympanic portion of temporal bone.
- Posterior wall:
 - o Mastoid portion of temporal bone.
- Superior wall:
 - o Squamous portion of temporal bone.
- Medial end of the bony canal is marked by a groove, tympanic sulcus, which is absent superiorly.
- **Tympanic bone makes up the greater part of the canal**, and also carries the sulcus.
- 2 suture lines in the canal wall:

1. TympanoSquamous:

- Anteriorly
- Transmits Auricular branch of Glossopharyngeal nerve (**Jacobson's nerve**)

2. TympanoMastoid:

- Posteriorly
- Transmits Auricular branch of vagus Nerve (**Arnold's nerve**).
- Evident in the posteriorinferior portion of the canal wall during surgical procedures like elevation of the tympanomeatal flap.

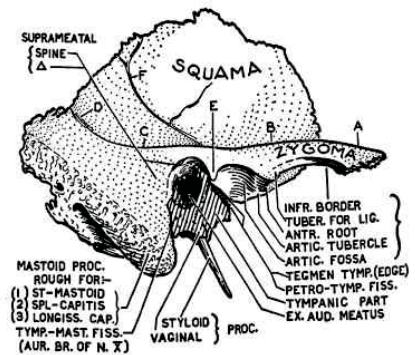
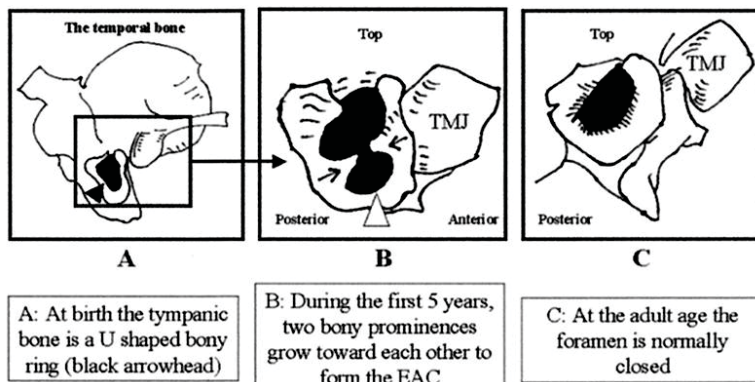


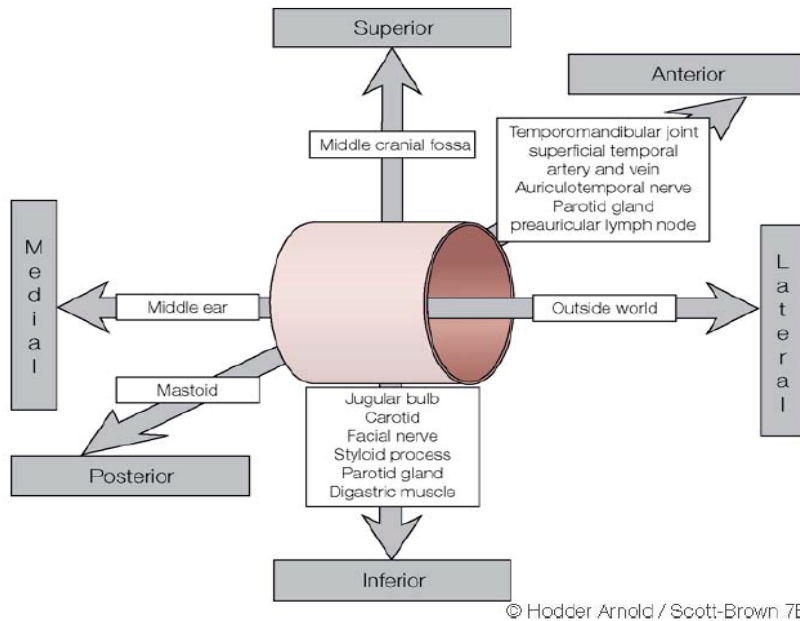
FIG. 835. Temporal Bone—lateral aspect



- Henle's spine:
 - o Projection produced by temporal bone in Postero-superior aspect of external auditory canal.
 - o Important landmark for mastoid surgery
- Isthmus:
 - o Narrowing in the bony canal.
 - o 6 mm lateral to tympanic membrane
 - o *2nd constriction.*
 - o *Narrowest part of EAC.*
- Anterior recess:
 - o Recess located in Antero-inferior part of the deep meatus beyond the isthmus
 - o Acts as a cesspool for discharge and debris in cases of external and middle ear infections.
- Condyle of the mandible and glenoid fossa produce a convexity in Anterior bony canal wall limiting the visualisation of the ear drum.
- This prominence and the Isthmus predispose foreign body entrapment in Antero-inferior portion of the medial end of the external canal and are difficult to remove.
- Foramen of Huschke:
 - o Deficiency in the Antero-inferior part of the bony canal.
 - o Found in children up to 4 years old or sometimes in adults.
 - o Connects the bony EAC to parotid and glenoid fossa.
 - o Permitting infections to and from the parotid)
- Skin covering the bony canal:
 - o Thin
 - o Devoid of hair and glands.
 - o Continuous over the tympanic membrane.
- *Skin lining the whole external canal is the only keratinising epithelium that lacks Eccrine glands.*

Relations of External Acoustic Meatus:

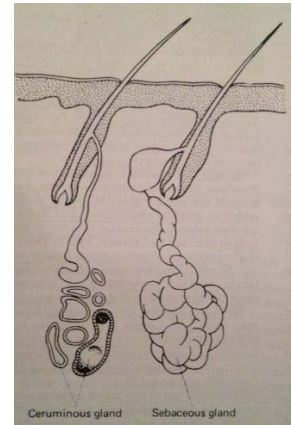
- Superiorly: Middle cranial fossa
 - Posteriorly: Mastoid air cells and the facial nerve
 - Inferiorly: Parotid gland
 - Anteriorly: Temporomandibular joint
 - Postero-superior part of deeper canal near the tympanic membrane is related to the mastoid antrum.
- ("Sagging" of this area may be noticed in acute mastoiditis)*



- **Nerve supply to External Auditory Canal:**
- Anterior wall and roof:
 1. Auriculotemporal (V_3) of Trigeminal nerve. (CN-V).
- Posterior wall and floor:
 1. Auricular branch of vagus (CN-X) (**Arnold's nerve**).
 2. Facial nerve also supply posterior wall.
 - o Hitzelberger sign: Numbness at facial nerve area in patient with acoustic neuroma.
- **Blood supply of External Auditory Canal:**
- Branches from External carotid Artery:
 - 1. Auricular branch of Superficial Temporal Artery:**
 - o Supply Roof and Anterior portion of the canal.
 - 2. Deep auricular Artery:**
 - o Branch of 1st part of maxillary artery.
 - o Supply Anterior wall of the canal and outer surface of TM
- **Vein drain in the external jugular, maxillary & pterygoid plexus**
- **Lymphatic drainage follows the auricle.**

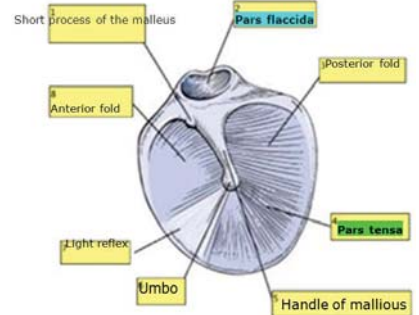
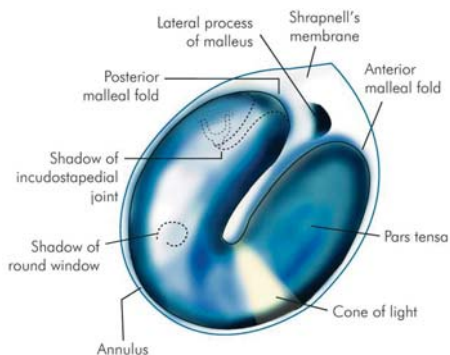
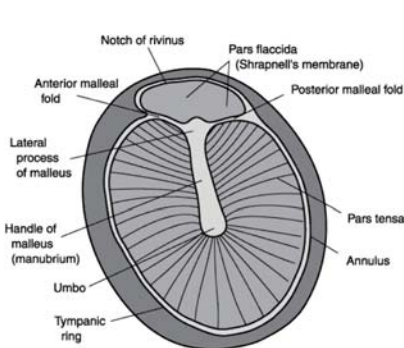
Physiology:

- Properties of External Auditory canal:
 - o Lateral growth of the epidermis with the consequence that layers of keratin are shed towards the surface opening of the external meatus.
 - o Rate of migration 0.05 - 0.1 mm/day.
 - o Same thing for epidermal layer of TM
- Volume of the external canal is about **0.85 ml²**.
- Normal flora of the outer ear canal is predominantly **Gram-positive Bacteria:** Staphylococcus epidermidis, Staphylococcus aureus, Diphtheroids (Corynebacterium).
- **Glands of External Auditory canal:**
 1. Ceruminous glands:
 - o Modified apocrine sweat glands.
 - o Simple coiled tubular gland
 - o Open into the root canal of the hair follicles
 - o Produce a watery, white secretion that slowly darkens
 - o Lay deep in the dermis
 2. Sebaceous gland
 - o Simple or branched alveolar glands
 - o Typical like elsewhere.
 - o Secrete sebum
 - o Form their secretion by passive breakdown of cells.
- **Wax:** Mixture of sebum (from sebaceous glands) + watery secretions (from ceruminous glands) + Desquamated epithelium.
 - Two distinct forms:
 1. Dry wax: Yellowish or gray
 2. Wet wax: Yellowish brown
- **Functions of Wax:**
 - Wax has acidic PH
 - Bacteriostatic properties.
 - Contains bactericidal enzymes, amino acids, and immuno globulins which helps to prevent infection.
 - Protecting tympanic membrane.
 - Keep moisture of ear canal.
 - has a self cleansing action
 - Traps the dirt and dust and move it outwards by migration of skin from the lateral part of tympanic membrane to outside.
 - With aging, Cerumen becomes harder, drier, less likely to be cleared due to atrophy of modified apocrine sweat glands.



3. Tympanic membrane

- At the medial end of the external auditory meatus.
- Between EAC and middle ear.
- Forms majority of the lateral wall of the tympanic cavity.
- Obliquely set
- Postero-superior part is more lateral than Antero-inferior part (EAC slightly longer Anteriorly)
- Oval in shape, being broader above than below.
- Forming an angle of about 55° with the floor of the meatus.
- Height 9-10 mm
- Width 8-9 mm
- Thickness 0.1 mm
- Surface Area: 70-80 mm²
- Vibrating surface area: 55 mm²
- Most of the circumference is thickened to form a fibrocartilaginous ring, the **tympanic annulus**, which sits in a groove in the tympanic bone, the tympanic sulcus.
- The sulcus does not extend into the notch of Rivinus at the roof of the canal, which is formed by part of the squama of the temporal bone.
- From the superior limits of the sulcus, the annulus becomes a fibrous band which runs centrally as anterior and posterior malleolar folds to the lateral process of the malleus
- Handle of malleus is clearly visible within the tympanic membrane.



- This leaves a small, triangular region of tympanic membrane above the malleolar folds within the notch of Rivinus, called the **pars flaccida** (Shrapnell's Membrane), which does not have a tympanic annulus at its margins.

- **Pars Tensa** forms the rest of the tympanic membrane and is concave towards the ear canal.
- Each segment is slightly convex between the lateral attachment of the annulus and the centre of the membrane where the tip of the malleus handle is attached at the umbo.
- Both the pars tensa and pars flaccida comprise 3 layers.
 1. Outer epithelial layer:
 - Epidermis.
 - Continuous with the skin of the external meatus.
 2. Middle fibrous layer:
 - Lamina propria.
 - Outer radiating fibrous layer.
 - Inner circular fibrous layer.
 3. Inner mucosal layer:
 - Continuous with the lining of the tympanic cavity)
- In the pars flaccida, the lamina propria is less marked (thin) and the orientation of the collagen fibers seems random.

Normal TM:

1. Color:
 - Pearly grey.
 - Shiny.
 - Translucent.
 - No bulging or retraction.
2. Consistency:
 - Smooth.
3. Landmarks:
 - Cone-shaped light reflection of the otoscope light
 - Short process of malleus
 - Handle of malleus
 - Umbo
 - Anterior and posterior folds

Left TM



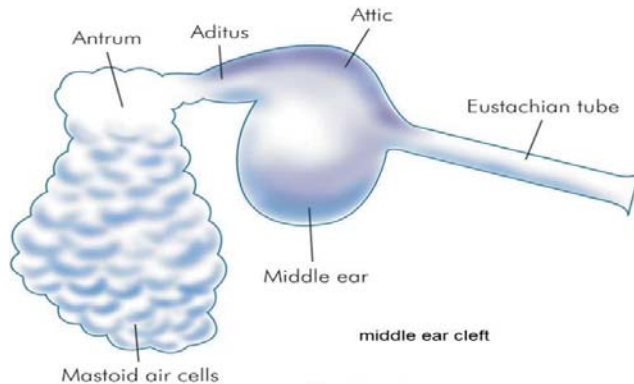
Right TM



- Blood supply of the tympanic membrane:
 - From branches supplying both the external auditory meatus and the middle ear.
 - Interconnect through extensive anastomoses within the connective tissue layer of the lamina propria.
- 1. Epidermal vessels** from the **Deep auricular branch of the maxillary artery** coming from the external auditory meatus,
- 2. Mucosal vessels** arise from **Anterior tympanic branches of the maxillary artery, stylomastoid branch of the posterior auricular artery** and **probably from the middle meningeal artery.**
- Nerve supply of TM:
 1. Anterior half of lateral surface:
 - Auriculotemporal (V_3) of Trigeminal Nerve (CN-V)
 2. Posterior half of lateral surface:
 - Auricular branch of vagus (CN X) (Arnold's nerve).
 3. Medial surface:
 - Tympanic branch of CN IX (Jacobson's nerve).

- Middle Ear Cleft:

1. Middle ear
2. Eustachian tube
3. Aditus
4. Antrum
5. Mastoid air cells



- Lined by mucous membrane and filled with air within the temporal bone.
- Extends much beyond the limits of tympanic membrane which forms its lateral boundary and is sometimes divided into:

1. Epitympanum (Attic):

- o Area above the Pars Tensa, Medial to Pars Flaccida and scutum and lateral to Lateral SCC prominence.

2. Mesotympanum:

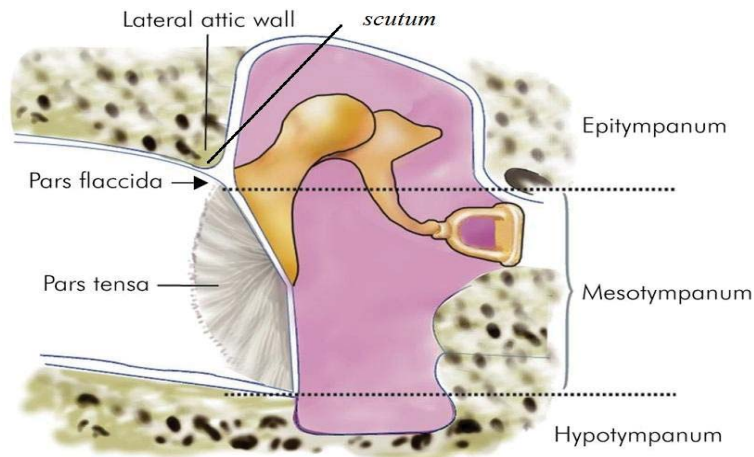
- o Area opposite to Pars Tensa.

3. Hypotympanum:

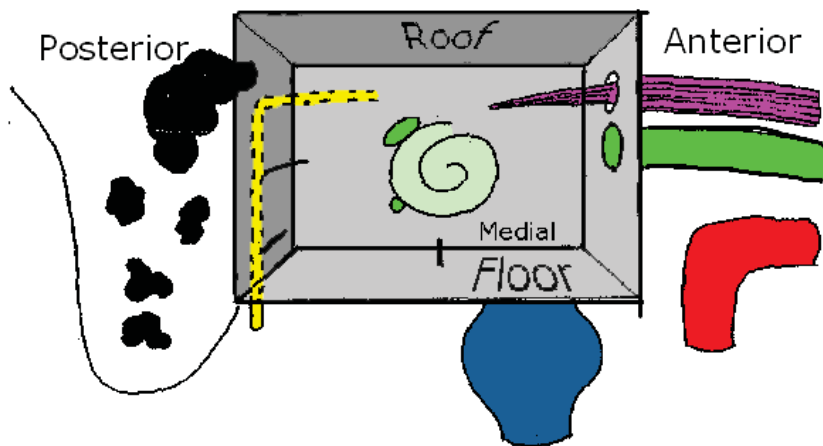
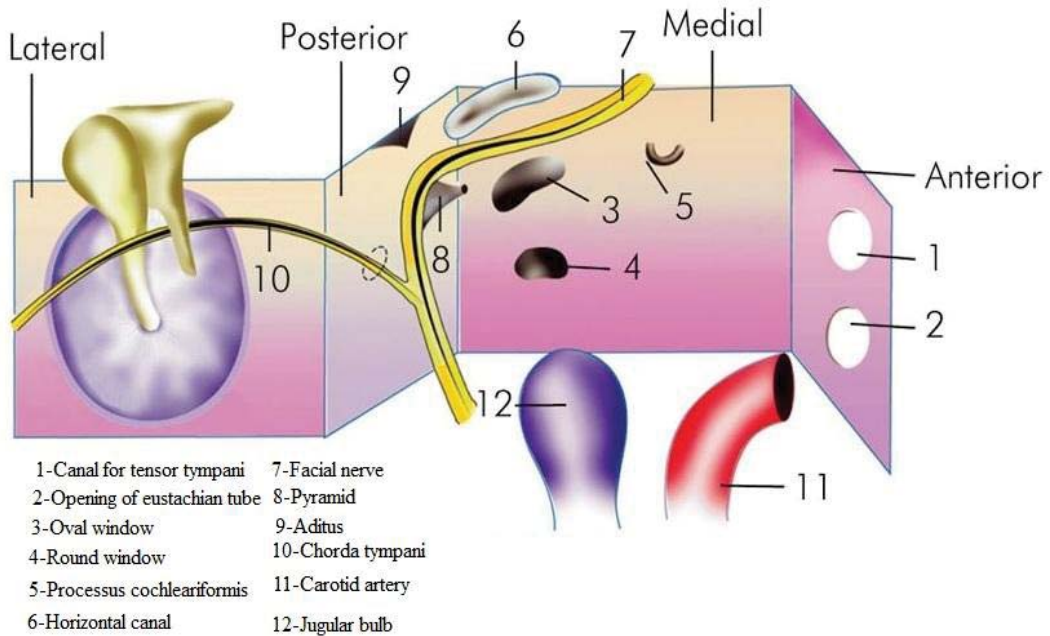
- o Area below the level of Pars Tensa.

4. Protympanum:

- o Area around the tympanic orifice of the Eustachian tube.

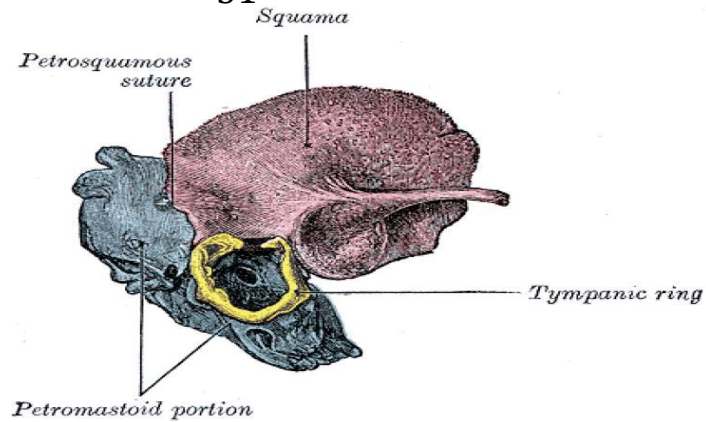


- Middle ear can be likened to a six-sided Box with a Roof, Floor, Medial, Lateral, Anterior and Posterior walls



Roof

- Thin plate of bone called **Tegmen Tympani**.
- Separates tympanic cavity from the dura of **Middle cranial fossa**.
- Extends posteriorly to form the Roof of the **Aditus and Antrum**.
- Formed from both **Petrous and Squamous** portions of temporal bone with suture line in between known as petrosquamous suture line.
- **PetroSquamous suture line**:
 - o Unossified in the young and close in adult life.
 - o Provide a route of access for infection into the extradural space in children .
 - o Veins from the tympanic cavity pass through this suture line to the **Superior Petrosal Sinus**.

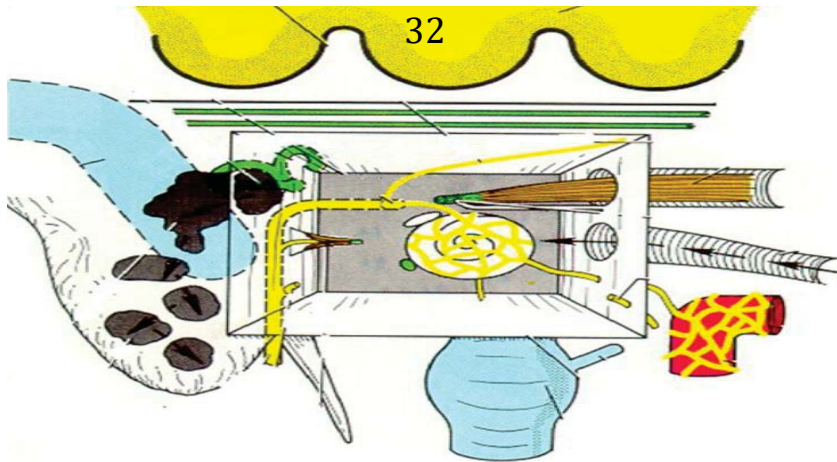


Floor

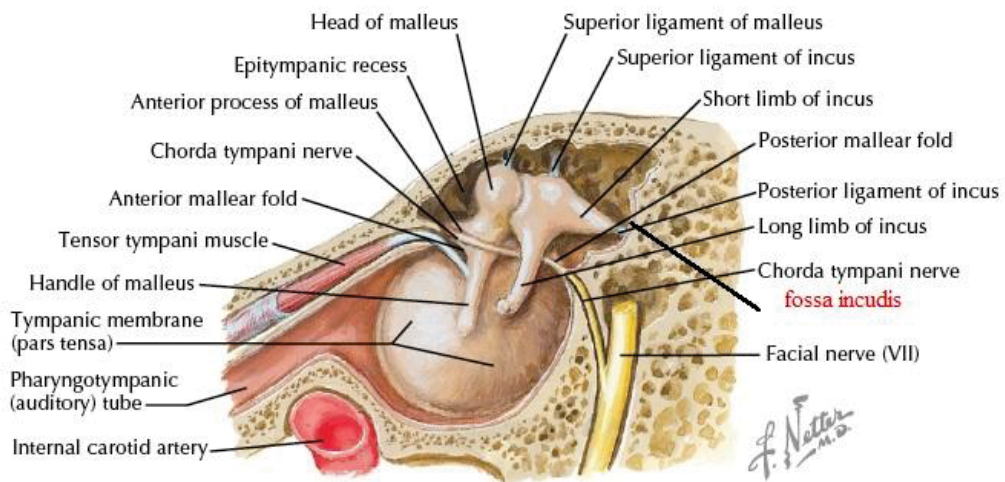
- Thin plate of bone.
- Narrower than the roof of the middle ear cavity
- Separates tympanic cavity from the **jugular bulb**.
- Its thickness can vary according to the height of the jugular fossa.
- Sometimes, it is congenitally deficient and the jugular bulb may then project into the middle ear; separated from the cavity only by **fibrous tissue & mucosa**.
- Tympanic Canaliculus:
 - o Small opening at junction of Floor and Medial wall of the cavity
 - o Allows the entry of **Tympanic branch of the Glossopharyngeal nerve** "**Jacobson's Nerve**" into the middle ear from its origin below the base of the skull.

Anterior wall

- o The narrowest wall because Medial and lateral walls converge anteriorly.
- o 5 openings perforates the Anterior wall.
- o **Lower 1/3 of Anterior wall:**
 - Thin plate of bone covering **Internal Carotid artery** as it enters the skull and before it turns Anteriorly.
 - Perforated by 3 openings:
 1. Superior and Inferior Caroticotympanic nerves carrying sympathetic fibers to the tympanic plexus.
 2. Tympanic branches of internal carotid artery.
- o **Middle 1/3 of Anterior wall:**
 - Perforated by 2 openings:
 1. Upper opening for the **Canal of Tensor Tympani Muscle** that subsequently runs along the medial wall of the tympanic cavity.
 2. Lower one for the **Eustachian tube** (oval and 5 x 2 mm in size)
- o **Upper 1/3 of Anterior wall:**
 - Pneumatized and may house the **Anterior Epitympanic sinus**.
 - Epitympanic recess:
 - o Small niche anterior to ossicular heads
 - o Can **hide residual cholesteatoma** in canal wall up surgery.



Lateral wall of tympanic cavity: medial (internal) view



Posterior Wall:

- Lies close to the mastoid air cells.

Aditus:

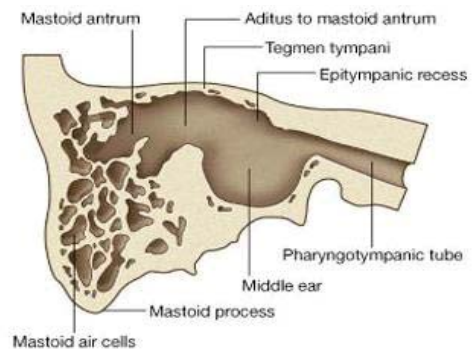
- o Opening through which Attic communicates with the antrum.
- o Lies above the pyramid, near the junction with the Roof of the middle ear.

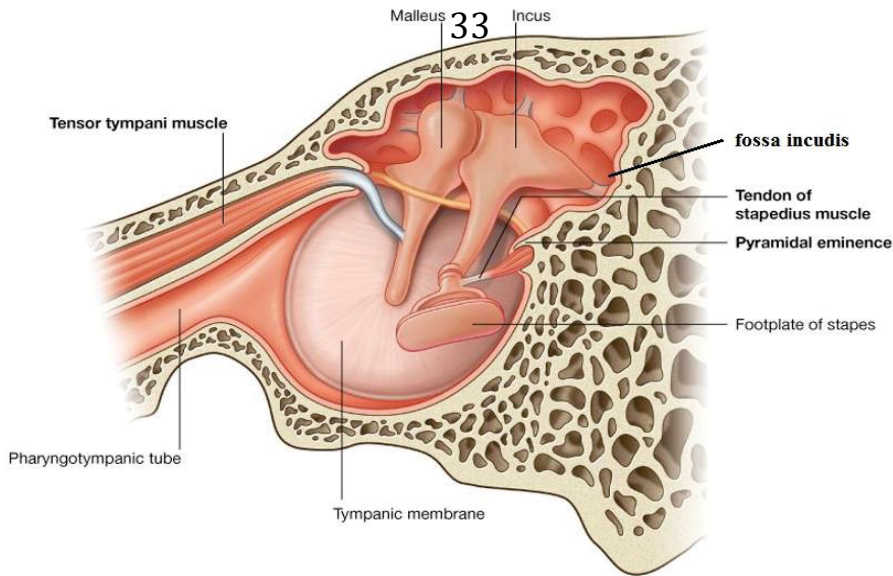
Fossa Incudis:

- o Small depression below the Aditus.
- o Houses:
 1. **Short process of Incus**
 2. **Short Incudal ligament.**

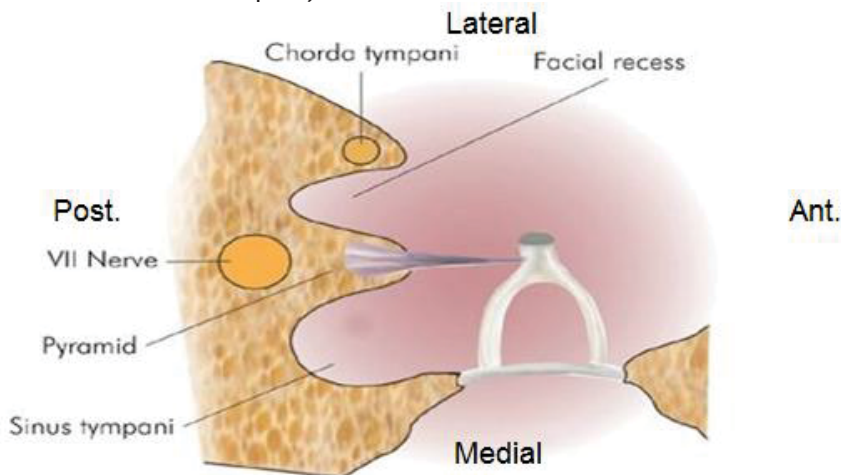
Pyramid:

- o Bony projection from the posterior wall with its apex pointing Anteriorly.
- o Below Fossa incudis.
- o Contains Tendon of Stapedius muscle to get attachment to the Neck of and Posterior crus of Stapes.



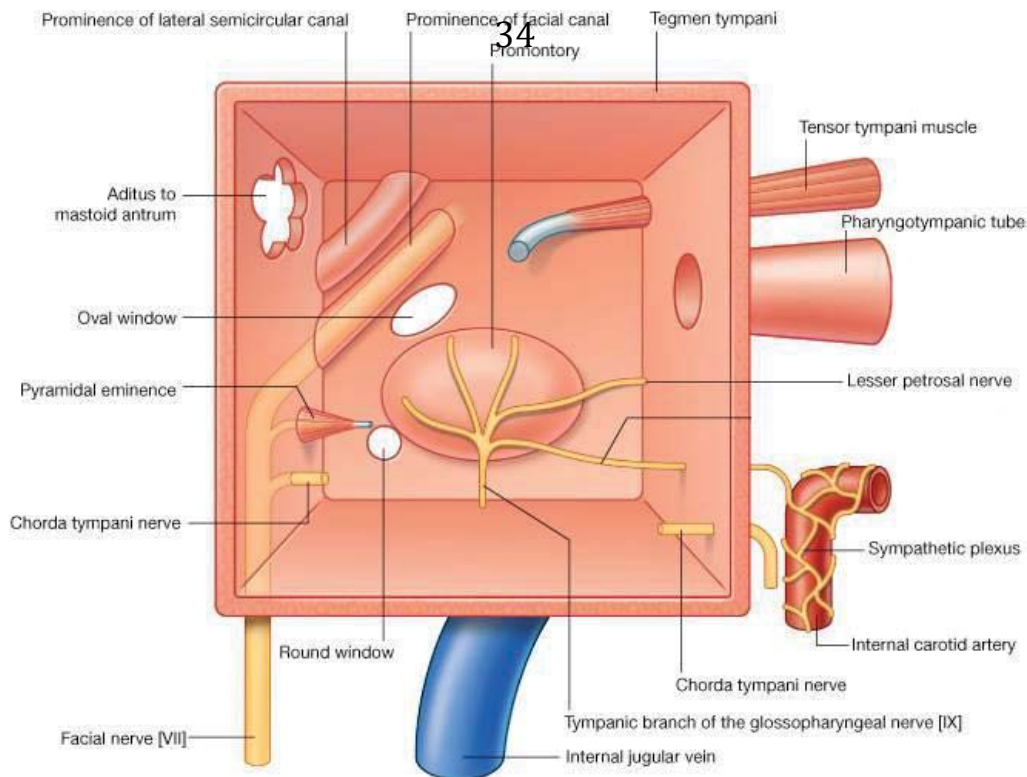


- **Facial Nerve:** Runs in the posterior wall just behind the **pyramid**.
- **Facial Recess:**
 - o Also called posterior sinus (supra pyramidal recess)
 - o Depression in the posterior wall **Lateral to Pyramid**.
 - o Bounded Medially by **Vertical part of Facial nerve (CN-VII)**
 - o Bounded Laterally by **Chorda tympani and tympanic annulus**.
 - o Bounded from Above by **Fossa incudis**.
 - o Surgically, facial recess is important, as direct access to the mesotympanum can be made through this into the middle ear without disturbing posterior canal wall (canal wall up or "intact canal wall technique").



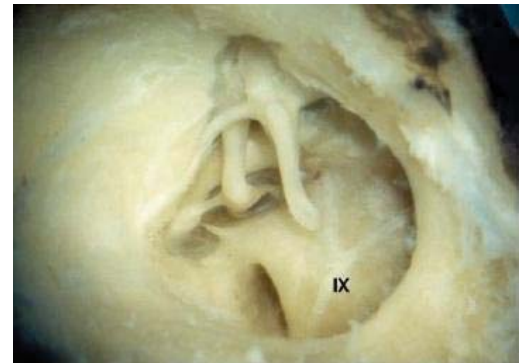
Facial recess lies lateral and sinus tympani medial to the pyramidal eminence and vertical part of the facial nerve.

- **Facial canal:** Passes Supero-inferiorly immediately posterior to the middle ear until it terminates at the stylomastoid foramen.
- **Posterior cranial fossa and sigmoid sinus** located posterior to the posterior wall

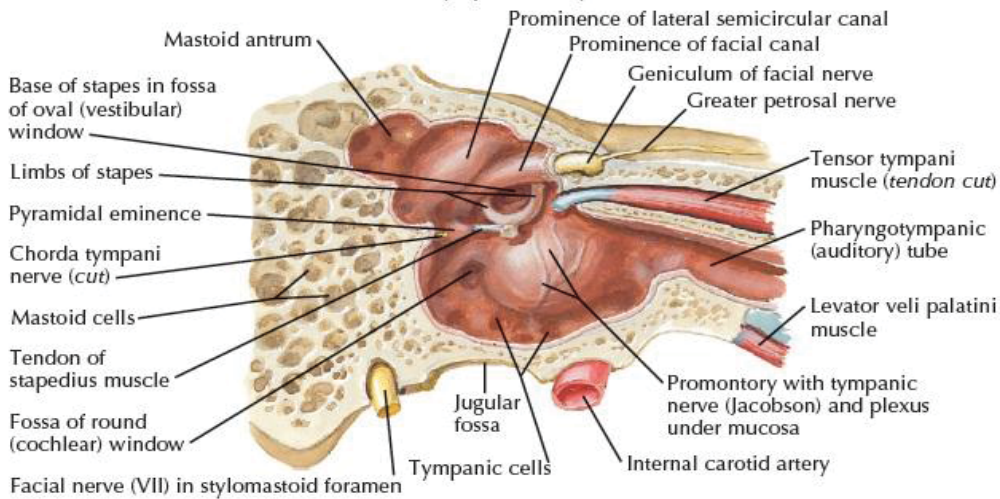


Medial wall

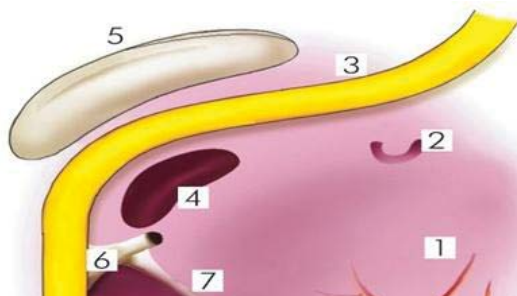
- Separates the tympanic cavity from the internal ear.
- **Promontory:**
 - o Most prominent portion in the medial surface due to the **basal coil of cochlea**
 - o Has small grooves on its surface containing the nerves which form **Tympanic plexus**.
 - o Sometimes the groove containing the **tympanic branch of the Glossopharyngeal nerve "Jacobson's Nerve"** may be covered by bone "small canal".
- **Oval window:**
 - o Also called Fenestra vestibuli.
 - o Located Posterior and Superior to the promontory.
 - o Connects tympanic cavity with vestibule
 - o Closed by foot plate of stapes and its surrounding annular ligament.
 - o Its size naturally varies with the size of the footplate, but on average it is **3.25 mm long and 1.75 mm wide**.
 - o The long axis of the fenestra vestibuli is **Horizontal**.
 - o Lies at the bottom of a depression or niche known as fossula that can be of varying width depending on the position of the facial nerve superiorly, and the prominence of the promontory inferiorly.



Medial wall of tympanic cavity: lateral view



- **Round window:**
- Also called Fenestra cochlea.
- Lies **Inferior and posterior** to oval window niche.
- Round window niche is most commonly **Triangular in shape, with Anterior, Posterosuperior and Posteroinferior walls.**
- Posterosuperior and posteroinferior walls meet posteriorly leading on to sinus tympani.
- **Subiculum** is Posterior extension of promontory separating oval and round windows.
- **Covered by the secondary tympanic membrane.**
 - o Membrane is usually out of sight, obscured by the overhanging edge of the promontory forming the niche and mucosal folds within it.
 - o Roughly oval in shape, about 2.3 x 1.9 mm in dimension.
 - o **Made up of Three layers: Outer mucosal, Middle fibrous and Inner endothelial layer.**
 - o Does not lie at the end of Scala tympani but forms part of its floor.
 - o It tends to curve towards the Scala tympani of the basal coil of the cochlea, so that it is **concave** when viewed from the middle ear.
 - o Ampulla of Posterior SCC is the closest vestibular structure to this membrane.
 - o Nerve supplying Ampulla of Posterior SCC (**Singular nerve**) runs 1 mm behind and parallel to the posterior portion of the membrane
 - o It is a landmark for the position of the singular nerve during surgical procedures like singular neurectomy for treatment of intractable BPPV.

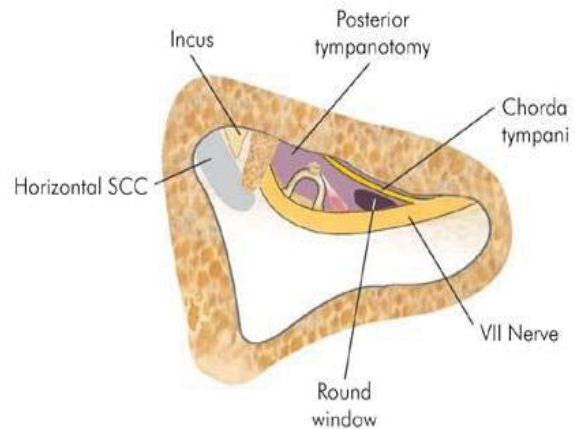


Medial wall of middle ear.

- 1 - Promontory
- 2 - Processus cochleariformis
- 3 - CN VII
- 4 - Oval window
- 5 - Horizontal canal
- 6 - Pyramid
- 7 - Ponticulus

- **Facial nerve Canal:** 36
- Also called Fallopiian canal.
- Runs Above promontory and oval window in an Antero-posterior direction.
- Behind the oval window, the facial canal starts to turn inferiorly as it begins its descent in the Posterior wall of the tympanic cavity
- Its bony covering may sometimes be congenitally dehiscent and the nerve may lie exposed making it very vulnerable to injuries or infection.
- Facial nerve canal is marked Anteriorly by **Processus Cochleariformis**
- It has a smooth rounded lateral surface that often has Microdehiscences and when the bone is thin or the nerve exposed by disease, there are **two or three straight blood vessels clearly visible along this line of nerve**. These are the only straight blood vessels in the middle ear and indicate quite clearly that the facial nerve is very close.

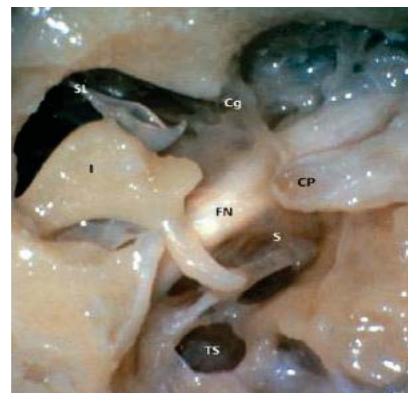
- **Prominence of Lateral SCC:**
- Above facial nerve canal.
- Forms Medial wall of the Epitympanum.
- Major feature of the Posterior portion of the Epitympanum, lying posterior and extending a little lateral to the facial canal.
- During a cortical mastoidectomy, the Triangular relationship of Lateral SCC, Short process of incus and Facial nerve is often quite helpful.



- In well aerated mastoid bones, labyrinthine bone over Superior SCC may be prominent, running at right angles to the lateral canal and joining it anteriorly at a swelling which houses the ampullae of the two canals.

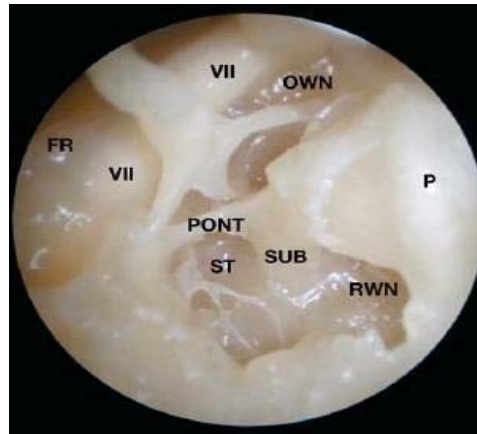
- **Processus Cochleariformis:**
- Hook-like projection just Anterior to the oval window.
- Tendon of Tensor Tympani takes a turn here to get attachment to the Neck of malleus.
- Cochleariform process also marks the level of the Geniculate ganglion of Facial nerve which is an important landmark for surgery of the facial nerve.

- **Cog Process:**
- Small bony bar Anterior and Superior to Cochleariform process which separates Anterior Epitympanum from rest of the attic.
- Facial Nerve runs **between** Cog process & cochleariform process.
- Geniculate ganglion lies deep and medial to cog.



Cg cog
Cp processus cochleariformis
I incus
S stapes
TS tympanic sinus

- **Sinus Tympani** (Infra Pyramidal Recess):
- Most constant depression present in Retrotympanic area.
- Posterior extension of mesotympanum and lies deep to both the promontory and the pyramid "facial nerve"
- Lies Medial to pyramid "facial nerve" .
- Bounded by the:-
 - o **Subiculum** Below.
 - o **Ponticulus** Above. "Arise from promontory above subiculum and runs to the pyramid on the posterior wall of the cavity"
- Occasions it can communicate with the mastoid air cells..
- The sinus can extend as far as 9 mm into the mastoid bone when measured from the tip of the pyramid.
- Its importance is that **cholesteatoma** (which has extended here from mesotympanum) can **hide** to which access is difficult.
- **Most Inaccessible site** in the middle ear and mastoid.

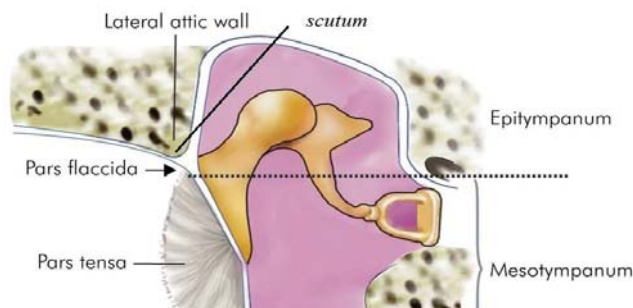


posterior medial wall of the tympanic cavity

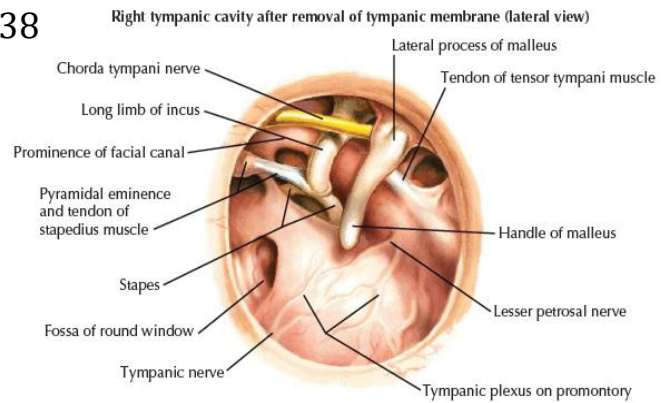
oval window niche (OVN).
round window niche (RWN).
promontory (P)
facial nerve (VII)
facial recess (FR)
The sinus tympani (ST)
ponticulus (PONT)
subiculum (SUB).

Lateral Wall:

- Separates middle ear from the external ear.
- Formed mainly by tympanic membrane, partly by the ring of bone into which this membrane is inserted.
- This ring of bone is incomplete at its upper part, forming a notch (notch of Rivinus), close to which are Three small openings.
- **Centrally:** Formed largely by **Tympanic membrane**, with the malleus attached to the membrane at the umbo
- **Superiorly:** Formed by **Scutum** "outer attic wall" bony lateral wall of Epitympanum
- **Inferiorly:** form by bony lateral wall of the **Hypotympanum**



- **Tympanic membrane:** Semitransparent and forms a 'window' into the middle ear.
- It is possible to see some structures of the middle ear through the normal tympanic membrane (**Long process of Incus, incudostapedial joint and the round window**).



- **Chorda Tympani nerve:**
 - o Enters the middle ear through Posterior Canaliculus.
 - o Runs on the medial surface of the tympanic membrane between the handle of malleus and long process of incus, Above the attachment of tendon of tensor tympani.
 - o Lies along the tympanic membrane and malleus until exiting through the Anterior Canaliculus.
- **Scutum:**
 - o Thin bone portion and **easily eroded** by cholesteatoma, leaving a telltale sign on a high resolution Coronal CT scan.
- Three openings present in medial surface of lateral wall of tympanic cavity:

1. Posterior Canaliculus:

- o Situated at junction of Lateral and Posterior walls of the tympanic cavity immediately behind the tympanic membrane.
- o Present at the level of Upper end of the handle of the malleus.
- o Leads to bony canal which descends through the posterior wall of the tympanic cavity in front of the facial nerve canal.
- o The canal ends in facial nerve canal near the Stylomastoid foramen.
- o Also known as canal for chorda tympani nerve.
- 1. **Chorda tympani nerve** Enters the tympanic cavity through this opening.
- 2. Transmits **Stylomastoid artery** which usually accompanies the chorda tympani nerve.

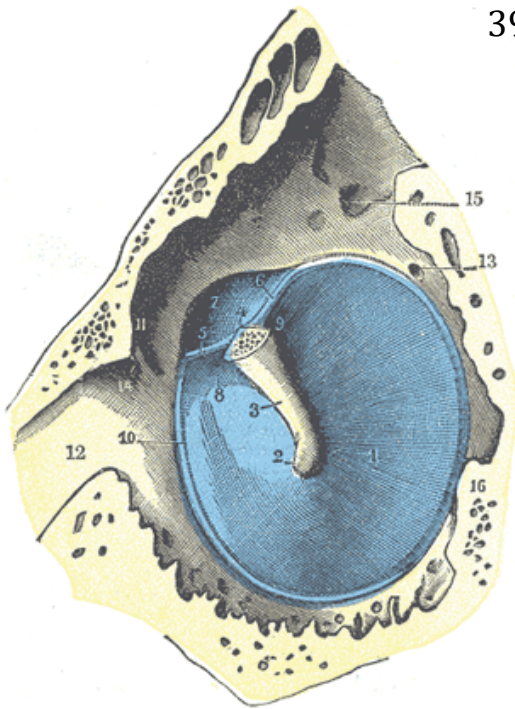
2. PetroTympanic (Glaserian) Fissure:

- o A small slit about 2 mm long which opens Anteriorly just above the attachment of the tympanic membrane.
- 1. Houses **Anterior Process of Malleus**
- 2. Receives the **Anterior malleolar ligament**.
- 3. Transmits **Anterior tympanic branch of maxillary artery** to Tympani cavity.
- 4. If the Anterior Canaliculus is inconsistent, **Chorda Tympani Nerve** leaves through this fissure.

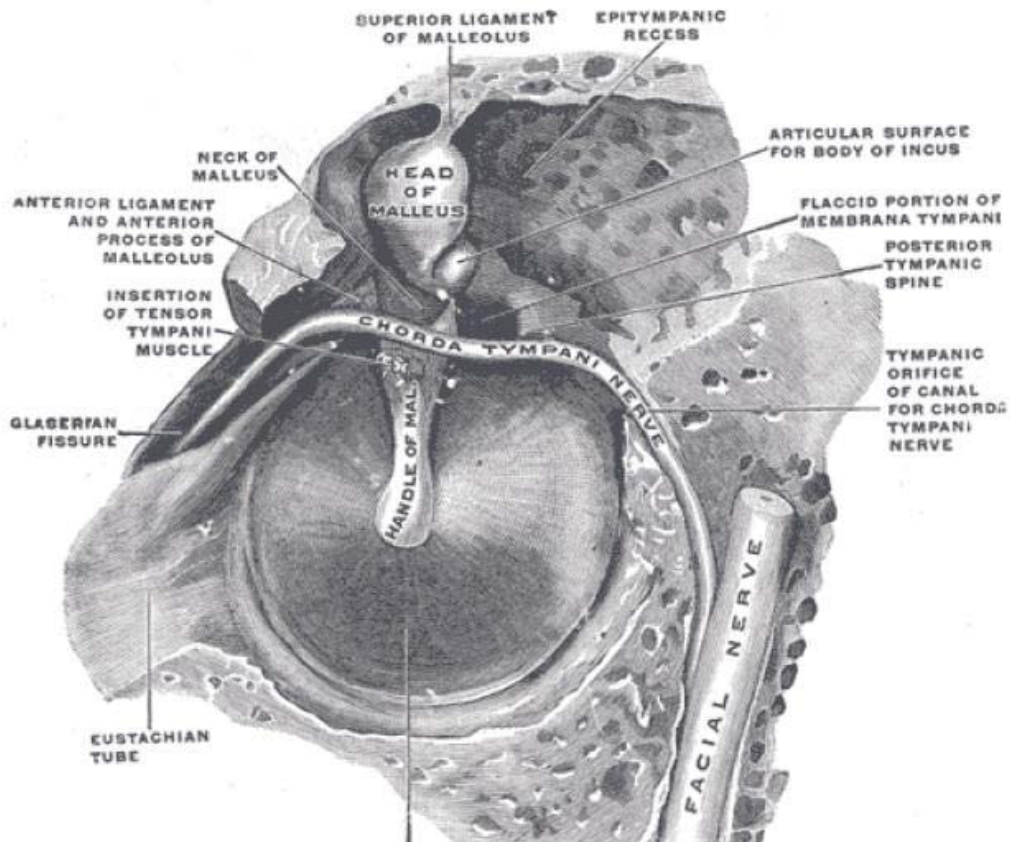
3. Canal of Hugier (Anterior canaliculus):

- o Lies medial to PetroTympanic (Glaserian) Fissure.
- o **Chorda tympani nerve** Leaves the tympanic cavity through this.

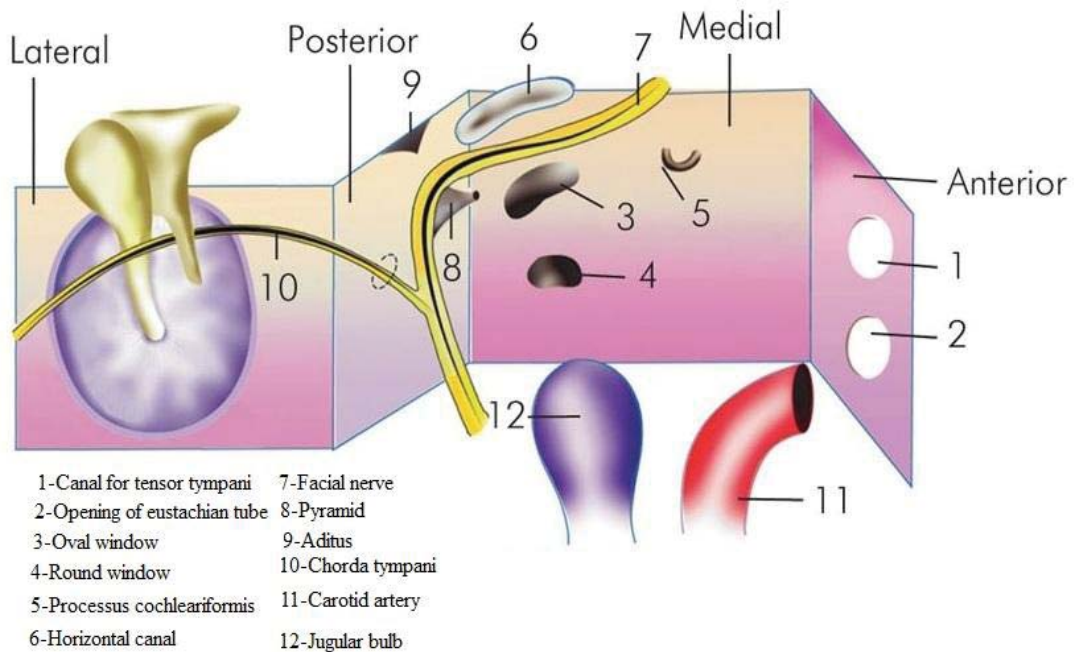
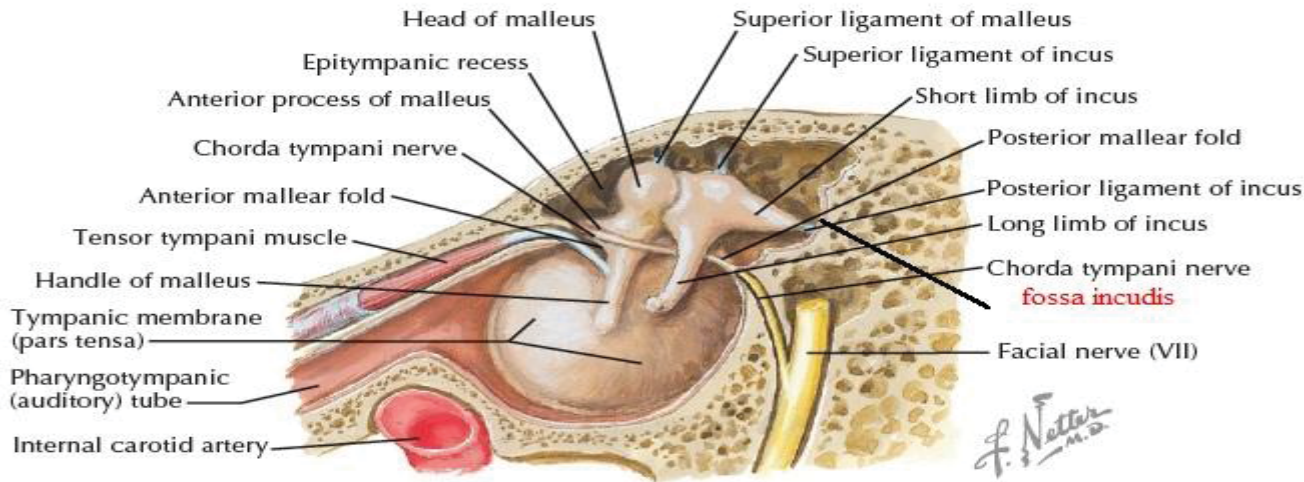
The tympanic membrane viewed from within.



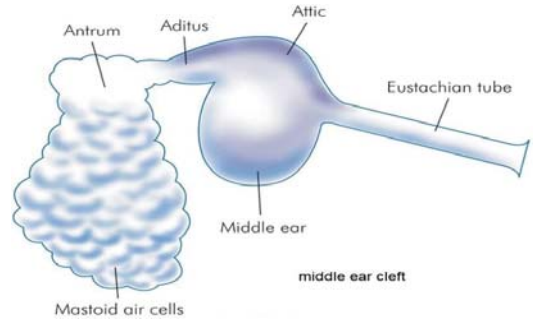
1. Tympanic membrane.
2. Umbo.
3. Handle of the malleus.
4. Lateral process.
5. Anterior tympanomalleolar fold.
6. Posterior tympanomalleolar fold.
7. Pars flaccida.
8. Anterior pouch of Tröltsch.
9. Posterior pouch of Tröltsch.
10. Fibrocartilaginous ring.
11. Petrotympanic fissure.
12. Auditory tube.
13. Posterior Canaliculus.
14. Canal of Huguier.
15. Fossa incudis for short crus of the incus.
16. Styloid prominence.



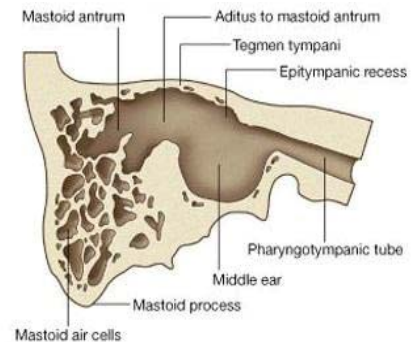
Lateral wall of tympanic cavity: medial (internal) view



- **Mastoid Antrum** 41
- Large, air-containing space in the upper part of mastoid (Petrus part of the temporal bone).
- Communicates with the attic through the aditus.
- Roof is formed by the **Tegmen Antri** which is a continuation of the **Tegmen Tympani** and separates it from the **Middle cranial fossa**.

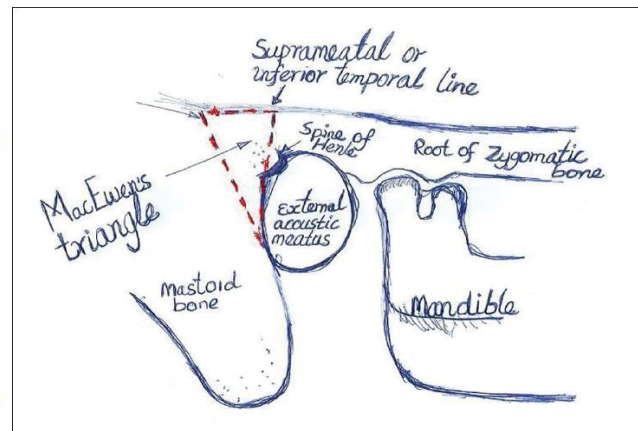
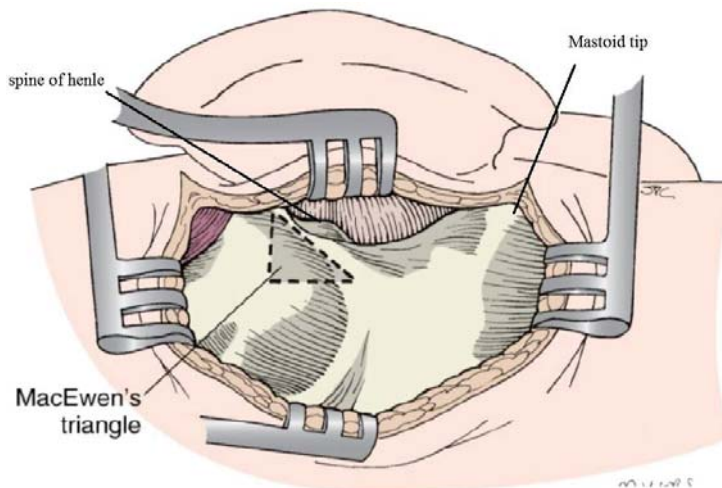


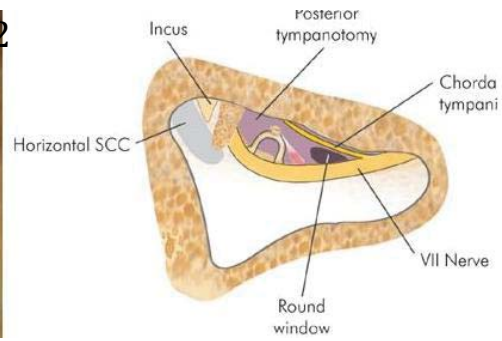
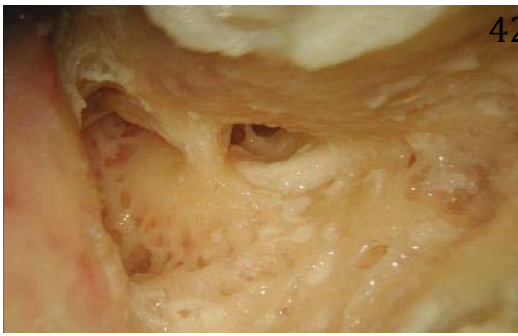
- Antrum (**NOT the air cells**) is well developed at birth.
- By adult life Antrum has a volume of 2 mL.
- Medial wall relates to **Posterior SCC**.
- Lateral wall is formed by a plate of bone which is on an average **1.5 cm** thick in the adult.



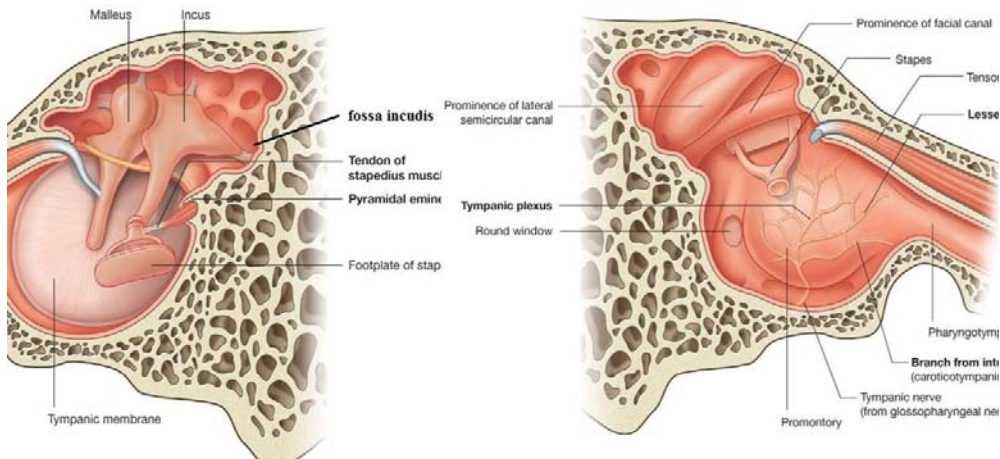
- This bone is marked externally on the surface of mastoid by **Suprameatal (MacEwen's) Triangle**:
 - o Important landmark to locate the mastoid in mastoid surgery.
 - o Located Postero-Superior to External auditory meatus.

- **Suprameatal (MacEwen's) triangle boundaries**:
 1. Superiorly by: Supramastoid crest (Temporal line)
 2. Anteriorly by: Postero-Superior margin of External auditory meatus. (**spine of henle**)
 3. Posteriorly by: Vertical tangent to the posterior margin of meatus.





- **Aditus:**
- Opening through which the attic communicates with the antrum.
- Lies between:
 - o **Medially:** The bony prominence of the horizontal SCC
 - o **Laterally:** Fossa Incudis to which is attached the short process of incus.
- Facial nerve courses just below the aditus.



- **Mastoid and Its Air Cell System:**
- Mastoid consists of bone cortex with a "honeycomb" of air cells underneath.
- Acting as a reservoir of air to limit pressure changes within the middle ear.
- Facial nerve is embedded in bone in its Petrous part but exits at the stylomastoid Foramen.
- In infants, Mastoid process is undeveloped and the Facial nerve is very superficial.
- Mastoid process starts to develop at age of 1 year.
- Complete development at age of 2 years.
- Lining of the mastoid is a Flattened, Non-ciliated epithelium without goblet cells or mucus glands.

- Depending on development of air cell, three types of mastoid have been described :-

1. Well-Pneumatised:

- o Cellular.
- o Mastoid cells are well developed and intervening septa are thin.

2. Diploetic:

- o Mastoid consists of marrow spaces and a few air cells.

3. Sclerotic:

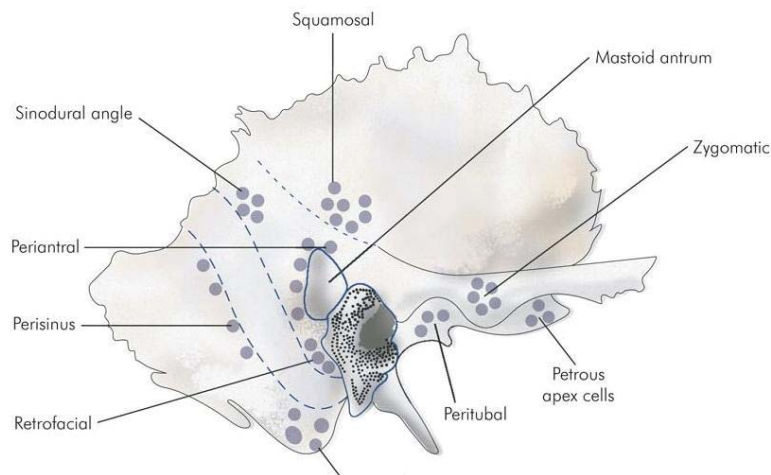
- o Acellular
- o No air cells or marrow spaces.
- o Occurs in 20 % of adult temporal bones.
- o Seen in individuals with Chronic ear disease.
- o Mastoid antrum may be the only air-filled space in the mastoid
mastoids & antrum is usually small and the sigmoid sinus is anteposed.

❖ **With any type of mastoid pneumatisation, Antrum is always present.**

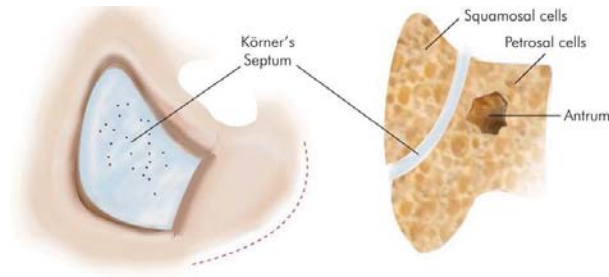
- Depending on the location, mastoid air cells are divided into:

1. **Zygomatic cells** (in the root of zygoma).
2. **Tegmen cells** (extending into the tegmen tympani).
3. **Perisinus cells** (overlying the sinus plate).
4. **Retrofacial cells** (round the facial nerve).
5. **Perilabyrinthine cells** (located above, below and behind the labyrinth, some of them pass through the arch of superior semicircular canal. These cells may communicate with the petrous apex).
6. **Peritubal** (around the eustachian tube. Along with hypotympanic cells they also communicate with the petrous apex).
7. **tip cells** which are quite large and lie medial and lateral to the digastric ridge in the tip of mastoid.
8. **Marginal cells** (lying behind the sinus plate and may extend into the occipital bone).
9. **Squamosal cells** (lying in the squamous part of temporal bones).

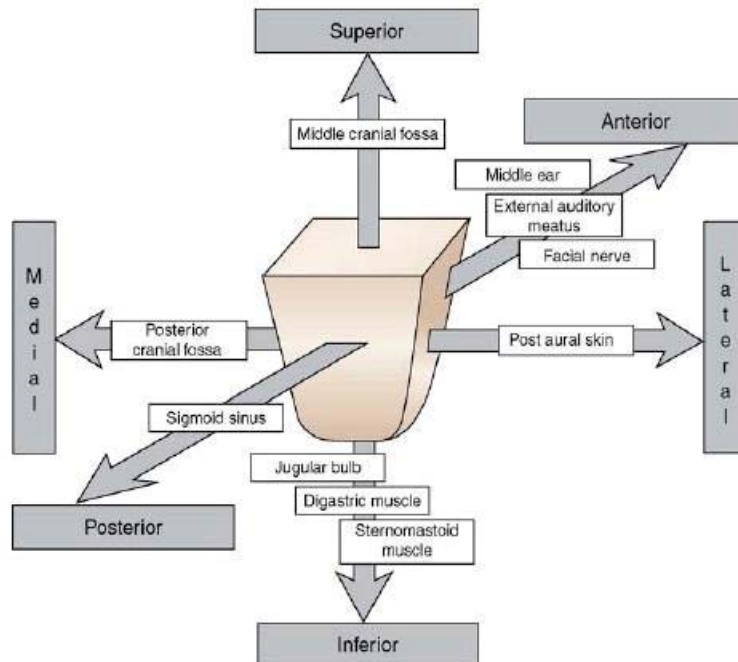
- Abscesses may form in relation to these air cells and may sometimes be located far from the mastoid region.

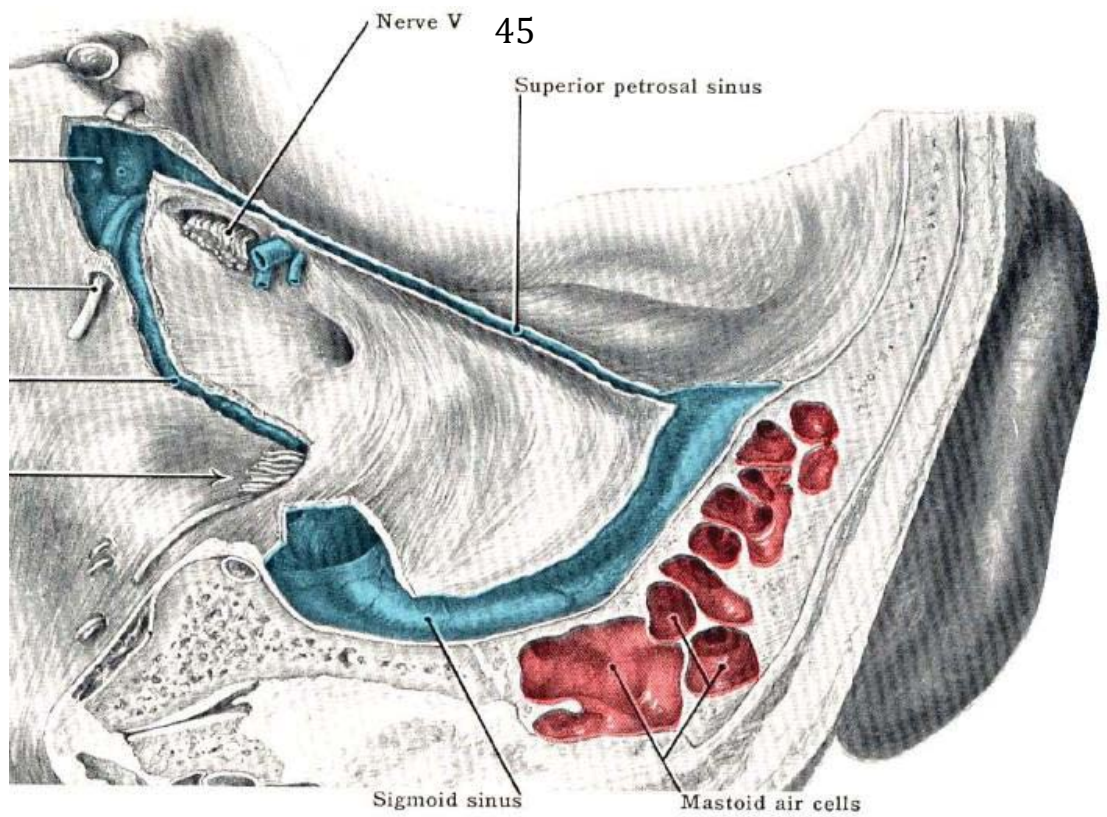


- **Development of Mastoid** 44
- Mastoid develops from **Squamous and Petrous bones**.
- Petrosquamosal suture may persist as a bony plate (**Korner's septum**) separating superficial squamosal cells from the deep petrosal cells.
- Korner's septum is surgically important as it may cause difficulty in locating Antrum and the deeper cells; and thus may lead to incomplete removal of disease at Mastoidectomy .
- Mastoid Antrum cannot be reached unless the Korner's septum has been removed.



- Posterior to mastoid is the **Sigmoid sinus**.
- It curves downwards only to turn sharply upwards to Pass medial to Facial nerve and then becomes the dome of the jugular bulb in the middle ear space.
- The posterior belly of the digastric muscle forms a groove in the base of the mastoid bone.

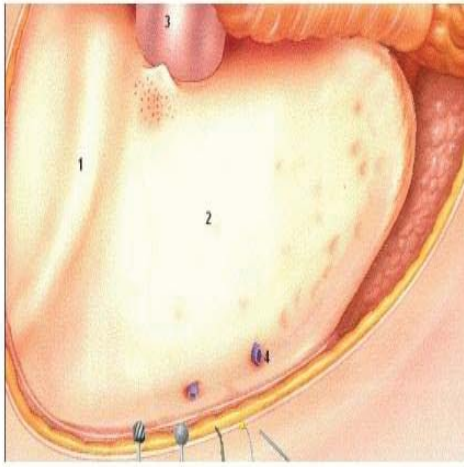




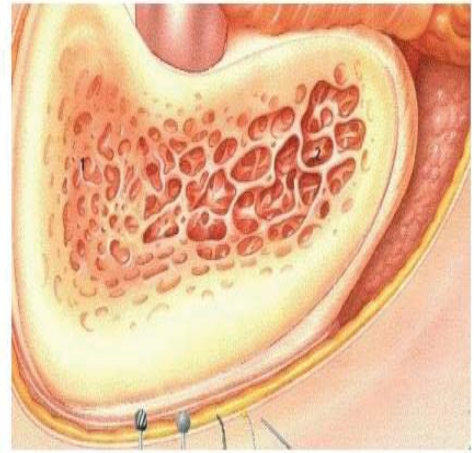
Air Cells—Dural Sinuses

Temporal Bone Dissection LATERAL APPROACH

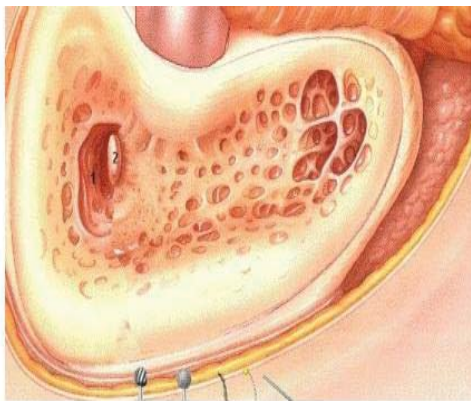
http://drfling.hyperphp.com/Notes/Temporal_Bone_Dissection_Lateral%20Approach.htm



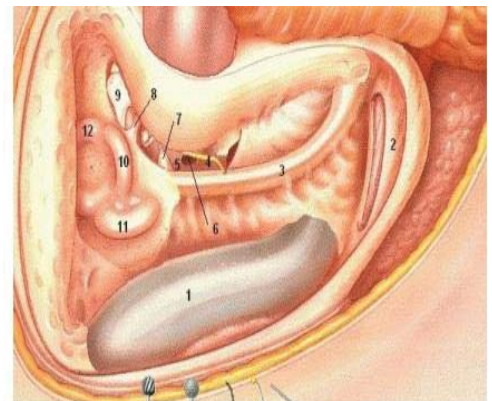
- 1. Temporal line
- 2. Mastoid cortex
- 3. External auditory canal skin
- 4. Emissary veins



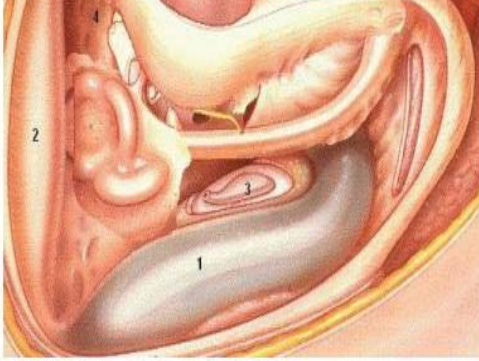
- 1. Koerner's septum
- 2. Mastoid air cells



- 1. Mastoid antrum
- 2. Horizontal semicircular canal



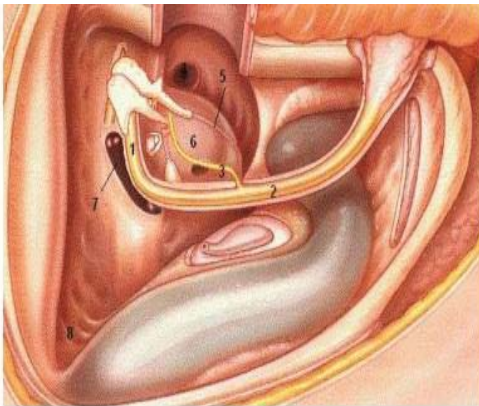
- 1. Sigmoid sinus
- 2. Digastric ridge and posterior belly of digastric muscle
- 3. Facial nerve (skeletonized mastoid segment)
- 4. Chorda tympani
- 5. Facial recess
 - triangle bound by: chorda tympani, facial nerve and incus buttress
- 6. Round window
 - opens into cochlear scala tympani
- 7. Pyramidal eminence containing stapedius muscle
- 8. Incus buttress
- 9. Incus body
- 10. Horizontal semicircular canal
- 11. Posterior semicircular canal
- 12. Superior semicircular canal



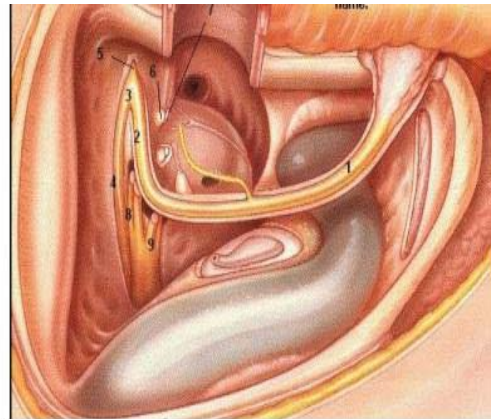
- 1. Sigmoid sinus
- 2. Tegmen tympani
- 3. Endolymphatic sac
 - in dura of posterior fossa between posterior SCC and sigmoid sinus
 - enters temporal bone at **operculum** which lies posteroinferiorly from IAC
 - lies at or below a line projected from axis of horizontal SCC (**Donaldson's line**)
- 4. Epitympanum



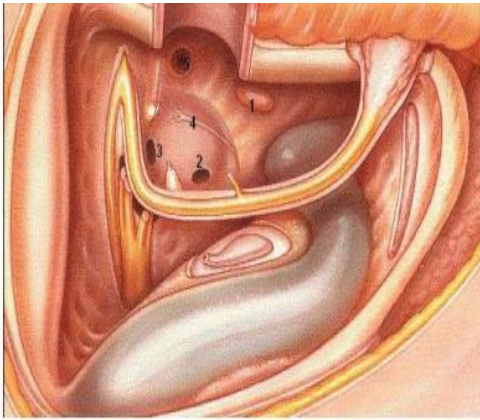
- 1. Jugular bulb
- 2. Facial nerve (mastoid segment)
- 3. Subarcuate artery
- 4. Posterior semicircular canal (ampullated end)
- 5. Superior semicircular canal (ampullated end)
- 6. Horizontal semicircular canal (ampullated end)
- 7. Facial nerve (tympanic segment)
- 8. Incus
- 9. Malleus



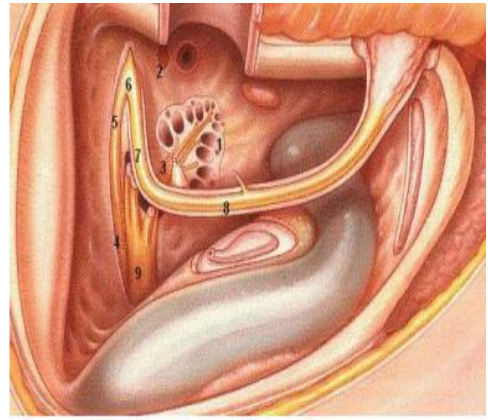
- 1. Facial nerve (tympanic segment)
- 2. Facial nerve (mastoid segment)
- 3. Chorda tympani
- 4. Eustachian tube
- 5. Jacobson's nerve (CN IX)
- 6. Promontory of cochlea
- 7. Vestibule
 - elliptical recess of utricle
 - spherical recess of saccule
- 8. Sinodural angle



- 1. Facial nerve (mastoid segment)
- 2. Facial nerve (tympanic segment)
- 3. Geniculate ganglion
- 4. Facial nerve (labyrinthine segment)
- 5. Greater superficial petrosal nerve
- 6. Cochleariform process
- 7. Tendon of tensor tympani
- 8. Superior vestibular nerve
- 9. Inferior vestibular nerve



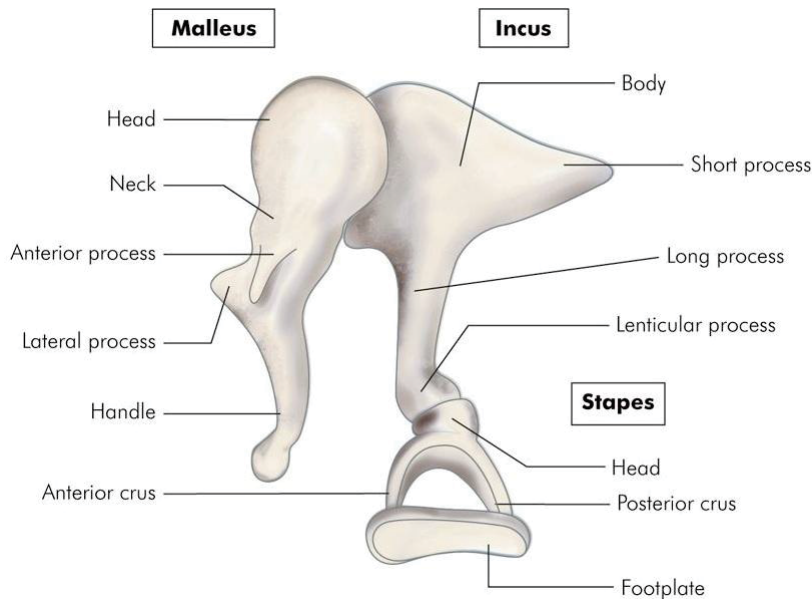
- 1. Internal carotid artery
- 2. Round window
- 3. Oval window
- 4. Jacobson's nerve and cochlear promontory



- 1. Cochlea
 - scala vestibuli ("superior" to basilar membrane in cochleostomy)
 - scala tympani ("inferior" to basilar membrane in cochleostomy)
- 2. Tensor tympani muscle (cut)
- 3. Cochlear nerve to modiolus
- 4. Facial nerve (meatal segment)
- 5. Facial nerve (labyrinthine segment)
- 6. GSPN
- 7. Facial nerve (tympanic segment)
- 8. Facial nerve (mastoid segment)
- 9. Vestibular nerve

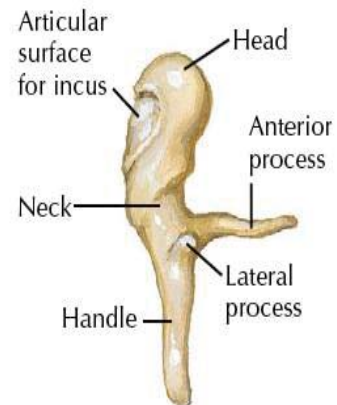
- **Contents of Tympanic cavity**
- Most important content of the middle ear is AIR which flows into the middle ear through a patent Eustachean tube.
- 3 Ossicles: (malleus - Incus - Stapes)
- 2 muscles: (Tensor Tympani - Stapedius)
- 2 Nerves: (Chorda tympani - Tympanic plexus).

- **Ossicles:**
- Three ossicles: Malleus (Hammer)- Incus (Anvil) - Stapes (Stirrup)
- Form a semi-rigid bony chain for conducting sound.
- Held in position by Ligaments, Muscles and Interossicular joints.
- Malleus is most Latero-Inferior and attached to TM.
- Incus is most Latero-Superior.
- Stapes is most medial and attached to the oval window.

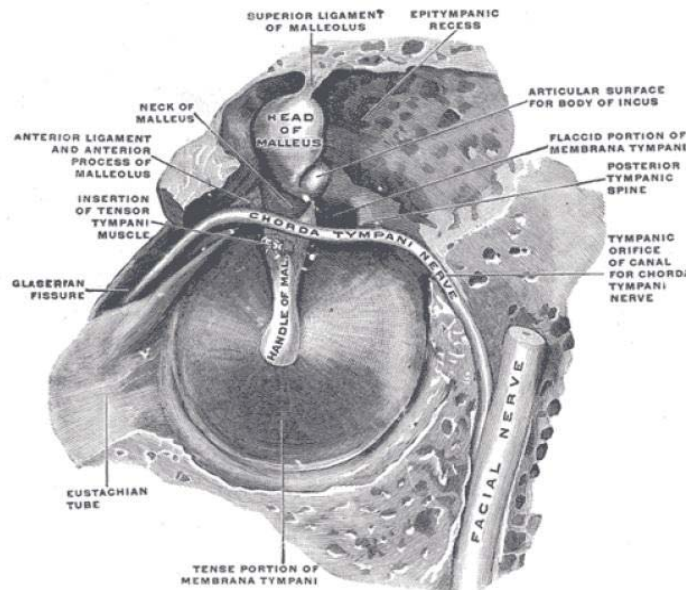


- **Malleus:**
- Largest ossicle
- Measuring up to 9 mm length
- Shape look like a Hammer
- Has Head, Neck and 3 processes (Handle, Lateral and Anterior Process) arising from below the neck.

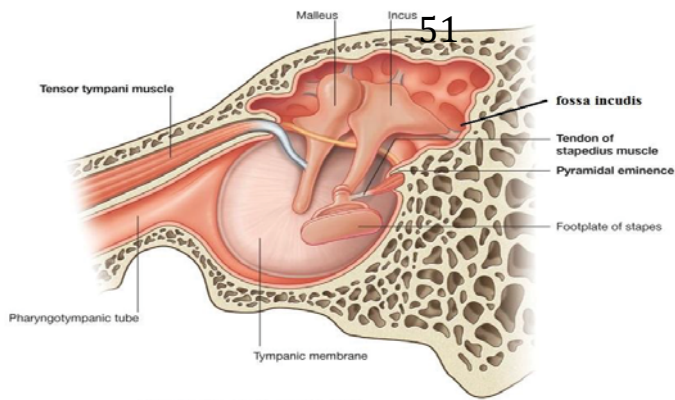
- **Head of malleus:**
- Lie in the Attic "Epitympanum".
- Divides Attic into anterior and posterior portion.
- During surgical procedures for attic cholesteatoma clipping of this head will improve the exposure in the attic region.
- Supported by superior ligament, which runs upward to Tegmen tympani.
- Has a saddle-shaped facet on its Postero-Medial surface to articulate with the Body of the incus by synovial joint.



- Cog:
 - o Projection in Lower part of Head of Malleus.
 - o NOT eroded by cholestelema and can be used as surgical landmark in mastoid surgery if handle of malleus is eroded by cholestelema.
- **Neck of malleus:**
 - Also lie in the attic "Epitympanum".
 - Below the neck the bone broadens and gives rise to Handle, Lateral and Anterior Process.
- **Handle of malleus (Manubrium):**
 - Runs downwards, Medially and slightly backwards between the mucosal and fibrous layers of the tympanic membrane.
 - Medial surface of handle, near its upper end, is a small projection into which the tendon of the Tensor tympani muscle inserts.
 - Its most prominent lower part is Umbo.
- **Lateral process of malleus:**
 - Forms a knob-like projection on outer surface of tympanic membrane.
 - Gives attachment to Anterior and posterior malleal (malleolar) folds from the tympanic annulus.
- **Anterior process of malleus:**
 - A slender Anterior ligament arises from anterior process to insert into the petrotympanic fissure



- Chorda tympani nerve crosses the **upper part** of Malleus Handle on its medial surface Above the insertion of Tendon of tensor tympani, but **below** the neck of the malleus itself.
- Neck of the malleus connects the Handle with the head and Amputation of the head by cutting through the neck leaves both chorda tympani and tensor tympani intact.

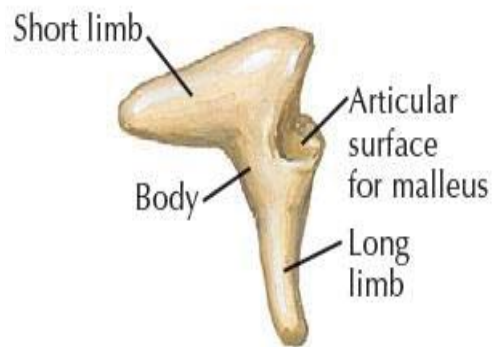


- **Incus:**

- has a body and 2 process (Short and Long process)
- Shape look like **Anvil**.
- Body and Short process lie in the Attic.

- **Body of Incus:**

- Has a cartilage-covered facet corresponding to that on the malleus.
- Body is suspended by the **Superior Incudal Ligament** that is attached to the tegmen tympani.



- **Short Process of Incus:**

- Projects backwards from the body to Lie in the Fossa incudis to which it is attached by a **Short suspensory ligament**

- **Long Process of Incus:**

- Hangs vertically and descends into the Mesotympanum behind and medial to the handle of the malleus
- At its tip, there is a small medially directed called **Lenticular process** attaches to the head of stapes.
- Long process of the incus has poor blood supply and prone for undergoing necrosis in disease conditions.
- 1st part to be eroded in cholesteatoma.

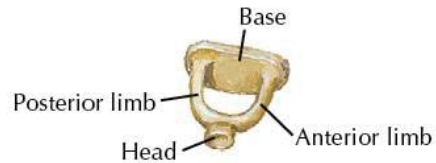


- **Lenticular process of Incus:**

- Sometimes been called the fourth ossicle because of its incomplete fusion with the tip of Long process of incus, giving the appearance of a separate bone or at least a sesamoid bone.

- **Stapes:**

- Has a head, neck, Anterior and Posterior crura (Limb) And a Footplate (Base)
- Footplate is held in oval window by Annular ligament.
- Shape look like Stirrup.



• **Head of Stapes:**

- Points laterally and has a small cartilage-covered depression for a synovial articulation with the Lenticular process of the Incus

• **Neck of Stapes:**

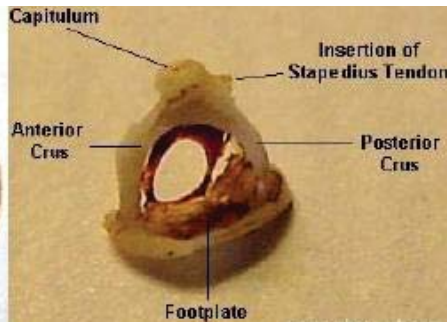
- Stapedius tendon inserts into Posterior part of Neck and Upper portion of Posterior crus.

• **Crura of Stapes:**

- Neck of the stapes gives rise to two crura.
- There is great variation in the shape of the two crura.
- Posterior crus is Longer than Anterior crus.
- Anterior crus is thinner and less curved than Posterior crus.
- The two crura join the footplate.

• **Footplate of Stapes:**

- Has a convex superior margin, and almost straight inferior margin and curved anterior and posterior ends.
- Average dimensions of the footplate 3 mm long and 1.4 mm wide
- It lies in the oval window where it is attached to the bony margins by the Annular ligament.
- Long axis of the footplate is almost horizontal, with the posterior end being slightly lower than the anterior.



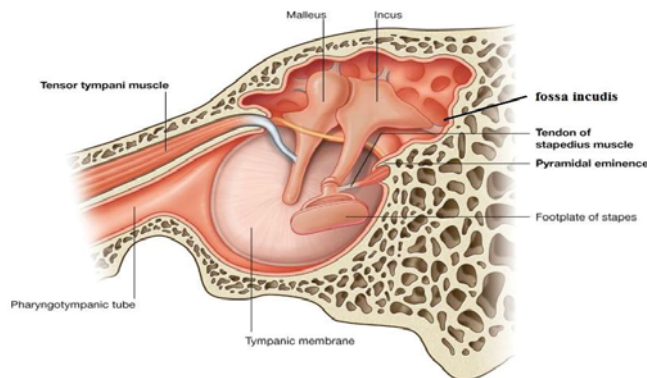
- **Ossicular joints are synovial type.**

- Malleo-incudal joint: Saddle joint
- Incudo-stapedial joint: Ball and socket joint.

- **Intratympanic Muscles:** 53
- 2 muscles: (Tensor tympani and Stapedius)

- Tensor Tympani Muscle:

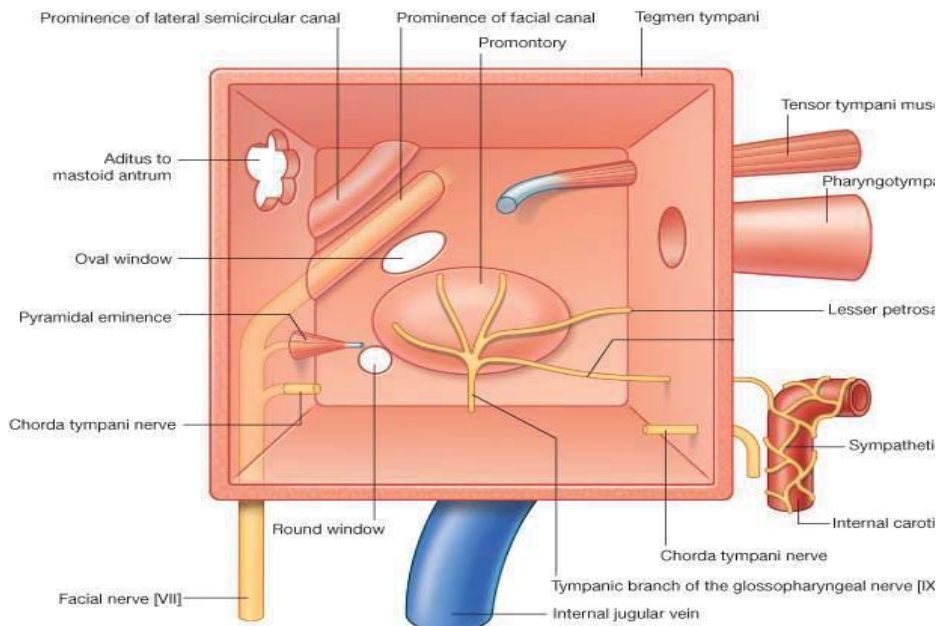
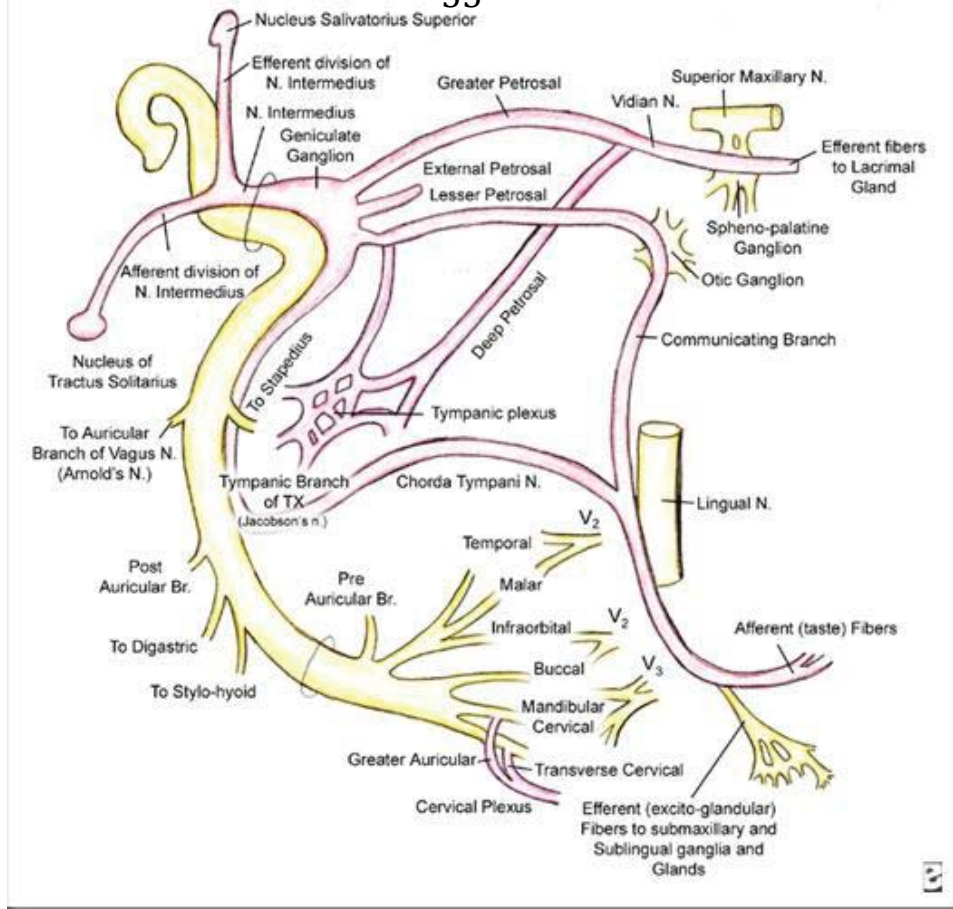
- 1st Arch Muscle.
- Supplied by Medial Pterygoid Nerve which is branch of Mandibular nerve (V₃) (Trigeminal Nerve)
- It is a long slender muscle arising from the walls of the bony canal lying above the Eustachian tube.
- Parts of the muscle also arise from the Cartilaginous portion of the Eustachian tube and Greater wing of the sphenoid.
- Then it passes backwards into the tympanic cavity lying on the medial wall of the middle ear just below the level of the facial nerve.
- The bony covering of the canal is often deficient in its tympanic segment where the muscle is replaced by its tendon.
- This tendon enters the **Processus cochleariformis** on the medial wall, where it is held down by a transverse tendon as it turns through a right angle to pass laterally and insert into the **Medial Aspect of Upper end of the Malleus Handle**.
- It tenses the tympanic membrane by holding the handle of the malleus thus helping the middle ear in better sound perception.



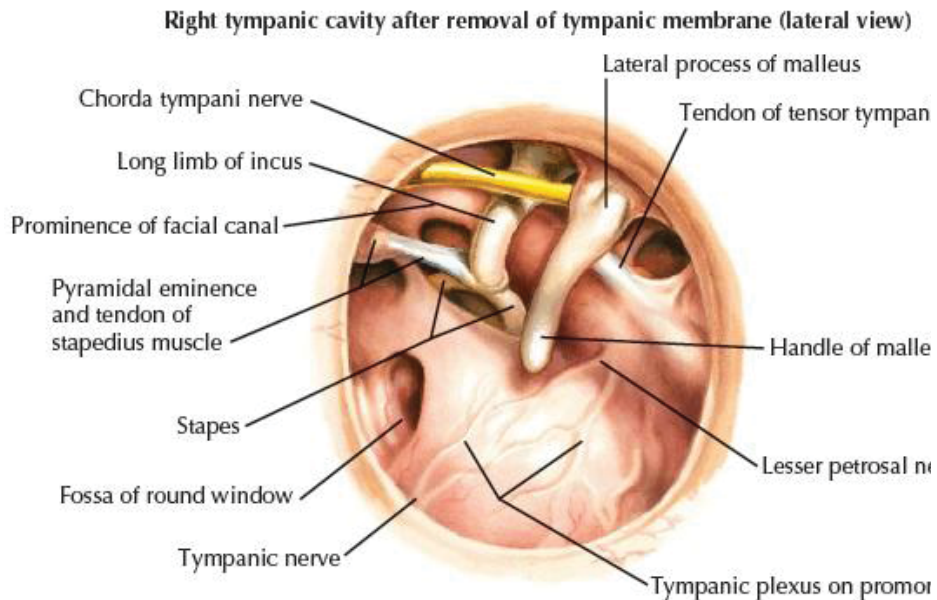
- Stapedius Muscle:

- 2nd arch muscle.
- Supplied by a branch of Facial nerve (CN-VII).
- Smallest muscle in the body.
- Arises from walls of the concial cavity within the pyramid.
- A slender tendon emerges from the apex of the pyramid and inserts into the **Neck and Posterior crus of stapes**.
- On contraction, this muscle rocks the stapes backwards holding it firm against the annular ligament preventing excessive transmission of sound into the inner ear.
- Protective role by dampen very loud sounds.
- Preventing noise trauma to the inner ear.
- Patients with facial nerve palsy have hyperacusis because of lack of action of this muscle.

- **Tympanic Plexus:** 54
- Lies on the promontory.
 - Formed by:
 1. Tympanic branch of Glossopharyngeal nerve . (Jacobson's nerve)
 2. Caroticotympanic nerves (sympathetic fibers from the plexus around the internal carotid artery).
 - Tympanic plexus gives innervations to:
 1. Medial surface of TM.
 2. Mucous membrane lining the tympanic cavity, Bony Eustachean tube, Mastoid Antrum and its air cells.
 3. **Secretomotor fibers** to Parotid gland.
 - Tympanic plexus provide the following branches:
 1. Branches to the mucous membrane lining the tympanic cavity, eustachean tube, mastoid antrum and its air cells
 2. A Deep branch joining the Greater superficial petrosal nerve.
 3. Lesser superficial petrosal nerve, which contain all the parasympathetic fibers of Glossopharyngeal nerve (CN-IX) to supply the parotid gland.
 - o **Lesser superficial petrosal nerve** leaves the middle ear through a small canal below the tensor tympani muscle where it receives parasympathetic fibers from Facial nerve (CN-VII) nerve by way of a branch from the geniculate ganglion.
 - o The full nerve passes through the temporal bone to emerge lateral to the greater superficial petrosal nerve on the floor of the middle cranial fossa, outside the dura.
 - o It then passes through the foramen ovale with the Mandibular nerve and Accessory meningeal artery to the otic ganglion.
 - o Post ganglionic fibers from the otic ganglion supply secretomotor fibers to the parotid gland by way of the auriculotemporal nerve.
 - Course of secretomotor fibers to the parotid:
 - Inferior salivary nucleus → CN IX → Tympanic branch → Tympanic plexus → Lesser petrosal nerve → Otic ganglion → Auriculotemporal nerve → Parotid gland.
 - o Section of Tympanic branch of glossopharyngeal nerve (**Jacobson's nerve**) can be carried out in the middle ear in cases of **Frey's syndrome**.
 - o Frey's syndrome are redness and sweating on the cheek area adjacent to the ear appear when the affected person eats as a side effect of parotid gland surgery or due to injury to Auriculotemporal nerve.
 - o Auriculotemporal branch of the Trigeminal nerve carries sympathetic fibers to the sweat glands of the scalp and parasympathetic fibers to the parotid gland.
 - o As a result of severance and inappropriate regeneration, the parasympathetic nerve fibers may switch course, resulting in sweating in the anticipation of eating, instead of the normal salivatory response.



- **Chorda Tympani Nerve:** 56
- Branch of Facial nerve (CN-VII)
- Enters the middle ear through **Posterior canaliculus**, at the junction of **Lateral and posterior walls**.
- Runs on the medial surface of the tympanic membrane between the Handle of malleus and Long process of Incus, above the attachment of tendon of tensor tympani.
- Continue forwards and leave by way of the **Canal of Hugier (Anterior canaliculus)**, which subsequently joins the **Petrotympenic fissure**.
- Carries **Taste from Anterior 2/3 of tongue**.
- Supplies **Secretomotor fibers to Submaxillary and Sublingual Salivary glands**.



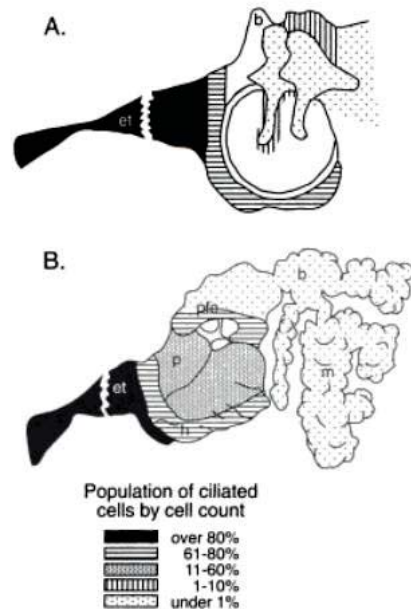
- **Lining of Middle Ear Cleft:**
- Mucous membrane of the Nasopharynx is continuous with that of Middle ear, Aditus, Antrum and Mastoid air cells.
- Histologically, Epithelium of middle ear cavity is varies according to the location.
- **Eustachian Tube Lining:**
- **Pseudostratified Ciliated Columnar Epithelium**
- With several mucous glands in the submucosa.
- At its nasopharyngeal end, the mucosa is truly respiratory; but in passing along the tube towards the middle ear, the number of goblet cells and glands decreases, and the ciliary carpet becomes less profuse.

- **Tympanic cavity Lining:** 57
- Antero-Inferior Compartment (Hypotympanum):
 - o Pseudostratified Ciliated Columnar Epithelium.
 - o The function of this compartment is devoted primarily to mucociliary clearance.
- Middle Compartment:
 - o Ciliated Cuboidal Epithelium.
- Postero-Superior compartment (Epitympanum and Mastoid):
 - o Flat Non-ciliated Epithelium.
 - o A gas exchange occurs in this compartment.

- Mucous membrane wraps the middle ear structures (ossicles, muscles, ligaments, and nerves) like **peritoneum** wraps various viscera in the abdomen, Raising several folds and dividing the middle ear into **various compartments**.

- As a result, **Only route for ventilation of Epitympanic space from Mesotympanum** is via 2 small openings between the various mucosal folds:

1. **Anterior isthmus tympani.**
2. **Posterior isthmus tympani.**

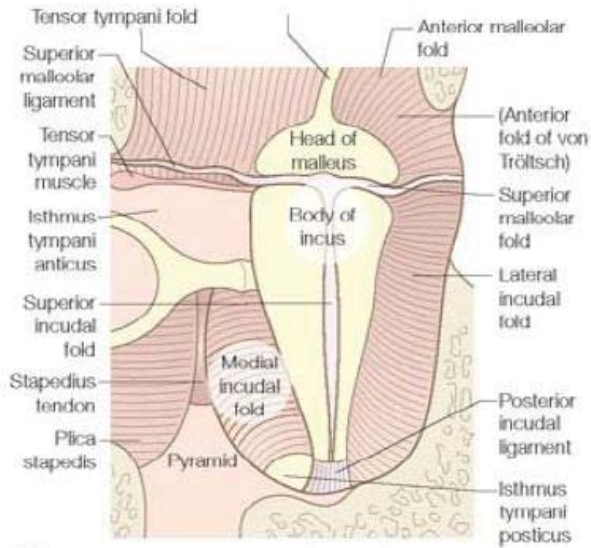


- **Prussak's Space:** = Superior recess of the tympanic membrane
- Bordered by:
 - **Laterally:** Pars Flaccida, Laterally
 - **Medially:** Neck of the Malleus.
 - **Inferiorly:** Lateral process of Malleus
 - **Superiorly:** Lateral malleolar fold.

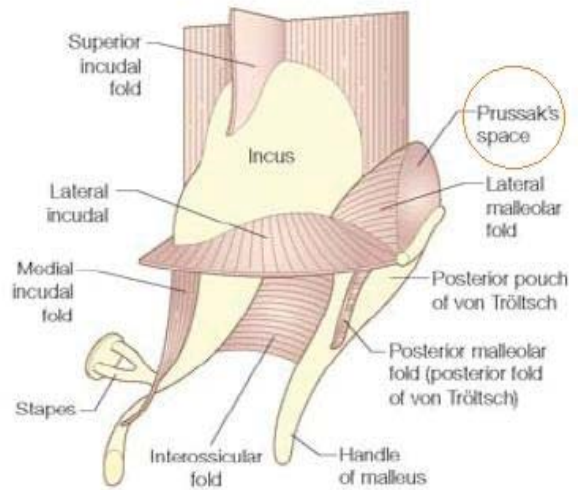
- This space can play an important role in the retention of keratin and subsequent development of cholesteatoma. (1st site of origin of cholesteatoma.)



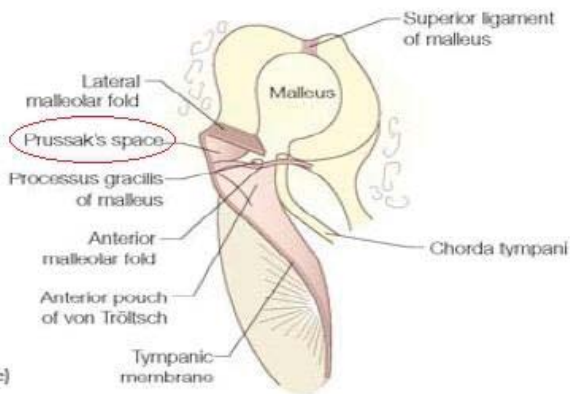
- **The mucosal folds have been described in detail by Figure below**



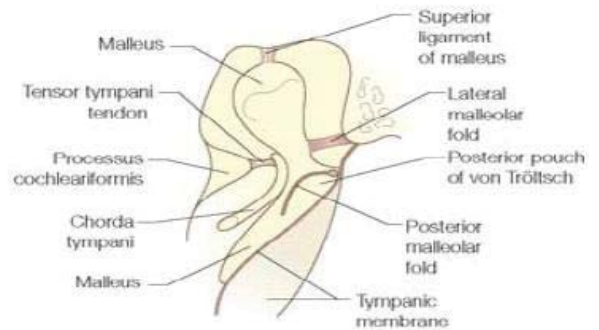
(a)



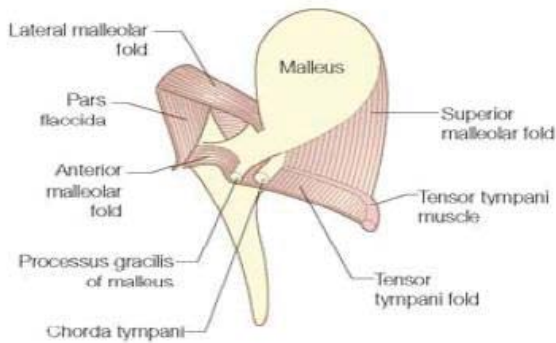
(b)



(c)



(d)



- **Blood Supply of Middle Ear**
- Middle ear is supplied by 6 Arteries.
- From both Internal and External carotid system.
- o **2 Main Arteries:**
 1. Anterior tympanic branch of Maxillary Artery:
 - o Supplies Tympanic membrane.
 2. Posterior tympanic branch of Stylomastoid Artery:
 - o Branch of Posterior Auricular Artery.
 - o Supplies Middle ear and mastoid air cells.
- o **4 Minor Arteries:**
 1. Petrosal branch of Middle Meningeal Artery:
 - o Runs along Greater Petrosal Nerve.
 2. Superior tympanic branch of Middle Meningeal Artery:
 - o Traversing along the canal for tensor tympani muscle.
 3. Branch of Artery of Pterygoid Canal:
 - o Runs along Eustachian tube.
 4. Tympanic branch of internal carotid.
- **Veins drain into:**
 1. Pterygoid venous plexus
 2. Superior Petrosal sinus

Branch	Parent artery	Region supplied
Anterior tympanic	Maxillary artery	Tympanic membrane; malleus and incus; anterior part of tympanic cavity
Stylomastoid	Posterior auricular	Posterior part of tympanic cavity; stapedius muscle
Mastoid	Stylomastoid	Mastoid air cells
Petrosal	Middle meningeal	Roof of mastoid; roof of epitympanum
Superior tympanic	Middle meningeal	Malleus and incus; tensor tympani
Inferior tympanic	Ascending pharyngeal	Mesotympanum
Branch from artery	Artery of pterygoid canal	Meso- and hypotympanum
Tympanic arches	Internal carotid	Meso- and hypotympanum

- **Lymphatic Drainage of Ear**
- Lymphatics from the middle ear drain into retropharyngeal and parotid nodes.
- Lymphatics of the Eustachian tube drain into Retropharyngeal group

Area	Nodes
Concha, tragus, fossa triangularis and external cartilaginous canal	Preauricular and parotid nodes
Lobule and antitragus	Infra-auricular nodes
Helix and antihelix	Post-auricular nodes, deep jugular and spinal accessory nodes
Middle ear and eustachian tube	Retropharyngeal nodes → upper jugular chain
Inner ear	No lymphatics

Inner Ear:

- Also called the internal ear or the labyrinth.
- Important organ of hearing and balance.
- Consists of:
 1. Bony labyrinth.
 2. Membranous labyrinth.

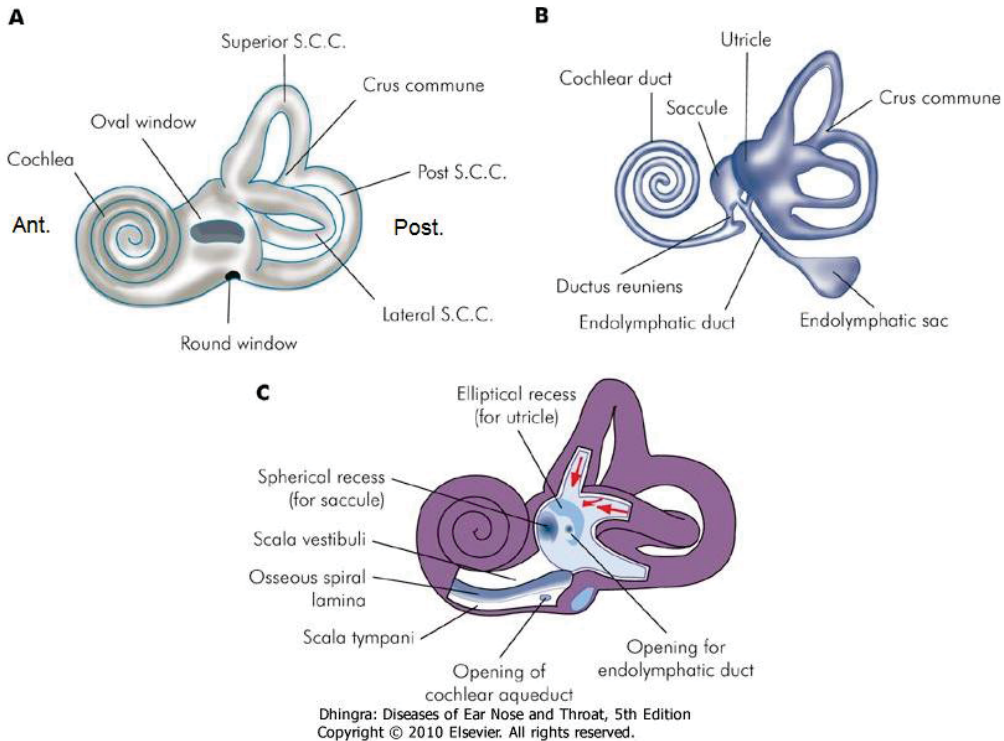


Figure 1.13 (A) Left bony labyrinth. (B) Left membranous labyrinth. (C) Cut section of bony labyrinth.

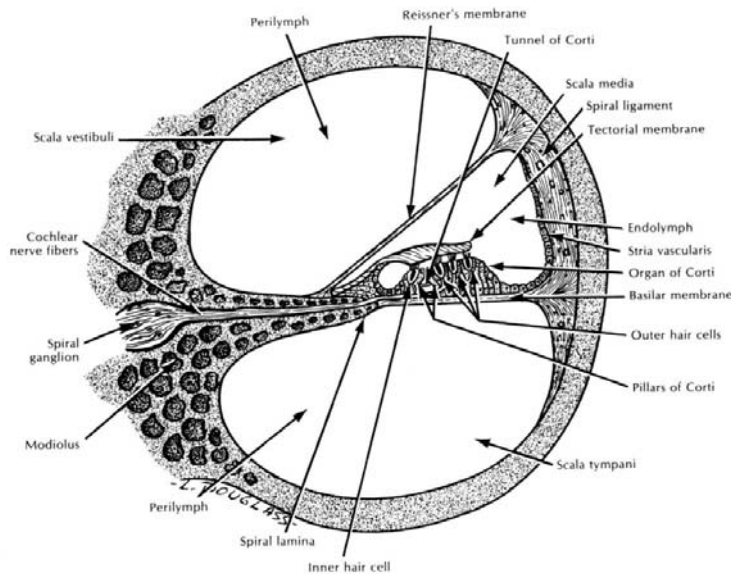
Bony Labyrinth:

- Located in the petrous portion of the temporal bone.
- Surrounds the membranous labyrinth and contains **Perilymph**.
- Consists of:
 1. Cochlea
 2. Vestibule.
 3. Semicircular canals.

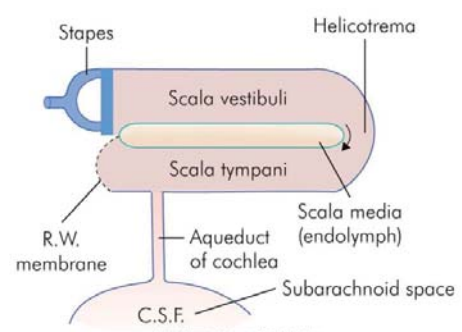
Otic capsule or the bony labyrinth ossifies from 14 centres, the first one appears in the region of cochlea at 16 weeks and the last one appears in the posterolateral part of posterior semicircular canal at 20th week.

1. Cochlea:

- Anterior portion of the bony labyrinth
- Contains the cochlear duct of the membranous labyrinth.
- Coiled tube making **2.5 - 2.75 turns** round a central pyramid of bone called the **modiolus**.
- Base of modiolus is directed towards internal acoustic meatus and carries branches of the cochlear nerve to the cochlear duct.
- Around the modiolus and winding spirally like the thread of a screw, is a thin plate of bone called **osseous spiral lamina**.
- It divides the bony cochlea incompletely, and gives attachment to the basilar membrane.
- **Spiral ganglion**: contains cell bodies of the cochlear nerve, located within the central modiolus in lateral end of cochlear nerve.
- The promontory (bony bulge in the medial wall of middle ear) is due to the basal coil of the cochlea.



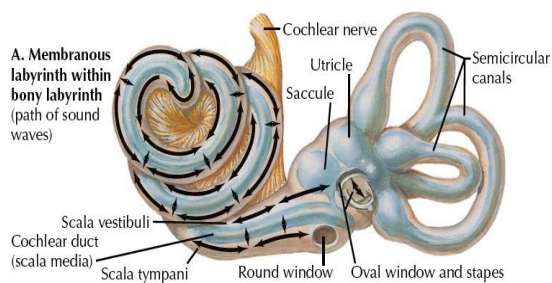
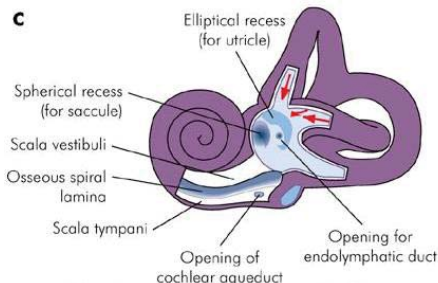
- The bony cochlea contains three compartments:
 1. Scala **V**estibuli.
 2. Scala **M**edia.
 3. Scala **T**ympani.

- **Scala Vestibuli**
 - o Filled with **Perilymph**.
 - o Begins in vestibule.
 - o Closed by the footplate of stapes over the oval window which separates it from the air-filled middle ear.
 - o Communicate with Scala tympani at the apex of cochlea through an opening called **helicotrema**.
 - **Scala Media**
 - o Also called Cochlear duct, Membranous cochlea
 - o Filled with **Endolymph**.
 - o Begins at round window
 - **Scala Tympani**
 - o Filled with **Perilymph**.
 - o Closed by secondary tympanic membrane.
 - o Connected with the subarachnoid space through the aqueduct of cochlea.
- 

Diagrams: Diseases of Ear Nose and Throat, 5th Edition
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Figure 1.15 Diagrammatic representation of perilymphatic system. CSF passes into scala tympani through aqueduct of cochlea.
- **Cochlear aqueduct** contains the **periotic duct**, allows perilymph to drain into CSF (Subarachnoid space), ends in posterior cranial fossa.

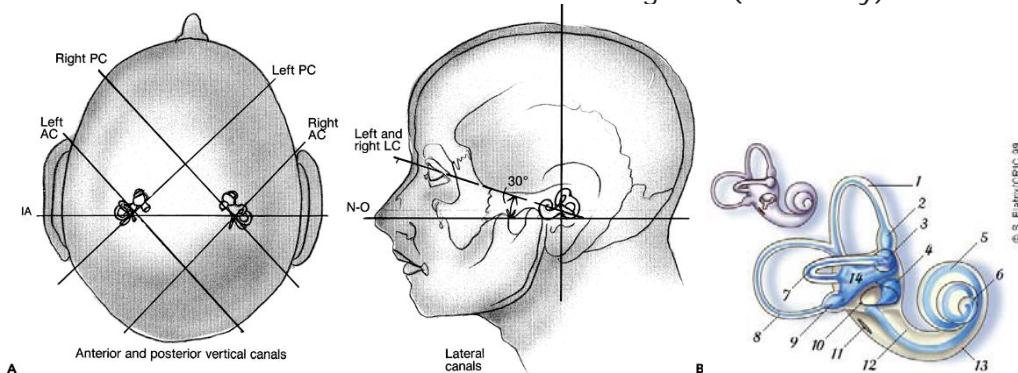
2. Vestibule:

- Middle portion of the bony labyrinth.
- Oval window lies in its lateral wall.
- Inside of its medial wall presents two recesses:
 1. Spherical recess: lodges the **Saccul** (Anterior)
 2. Elliptical recess: lodges the **Utricle** (Posterior)
- In the posterosuperior part of vestibule are the five openings of semicircular canals.
- **Vestibular Aqueduct** contains the **endolymphatic duct** and runs from the vestibule to the posterior surface of the petrous pyramid in the posterior cranial fossa (opening is the **operculum**)



3. Semicircular Canals (SCC):

- Posterior portion of the bony labyrinth.
- Three in number, **Lateral**, **Posterior** and **Superior**.
- Lie in planes at right angles to one another.
- Each canal has an **Ampullated end** which opens independently into the Utricle and a **Nonampullated end**.
- Cupula: gelatinous layer located within each ampulla, extends to the roof of the ampulla sealing the SCC.
- Cilia are embedded in the cupula; deflections of the cupula bends stereocilia.
- Membranous labyrinth turns with head, endolymph stays but due to inertial mass; causes pressure across cupula
- The three canals open into the vestibule by five openings.
- **Lateral (Horizontal) SCC:**
 - o Inclined 30 degrees from horizontal.
 - o AmpulloPetal flow of endolymph (**TOWARD** vestibule) **Increase** vestibular neuron firing rate (Excitatory).
- **Superior (Anterior) and Posterior SCC:**
 - o Vertical canals.
 - o Share one nonampullated ends **Crus commune**.
 - o AmpulloFugal flow of endolymph (**AWAY** from vestibule) **Increase** vestibular neuron firing rate (Excitatory).



Membranous Labyrinth:

- Located within the bony labyrinth and contains **Endolymph**
- consists of:
 1. Cochlear duct
 2. Saccule
 3. Utricle
 4. Three semicircular ducts
 5. Endolymphatic duct and sac.

1. Cochlear duct

- Also called membranous cochlea or the scala media.
- Blind coiled tube located within the bony cochlea.

- Triangular on cross-section and its three walls are formed by:

1. Basilar membrane:

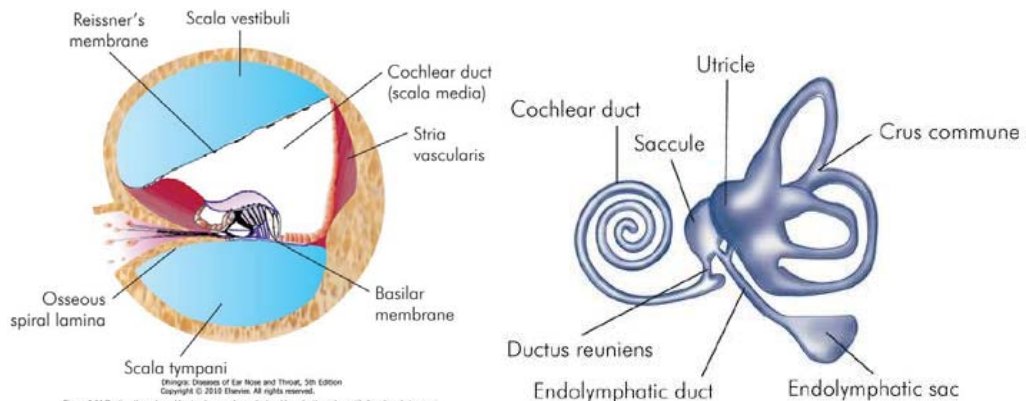
- o Floor of scala media.
- o Between scala media and scala tympani.
- o Supports the organ of corti.
- o **Base:** Stiffer and Thinner.
- o **High frequencies** of sound are heard at the Basal coil.
- o **Apex:** Flexible and Thicker.
- o **Lower frequencies** are heard at the Apical coil.

2. Reissner's membrane:

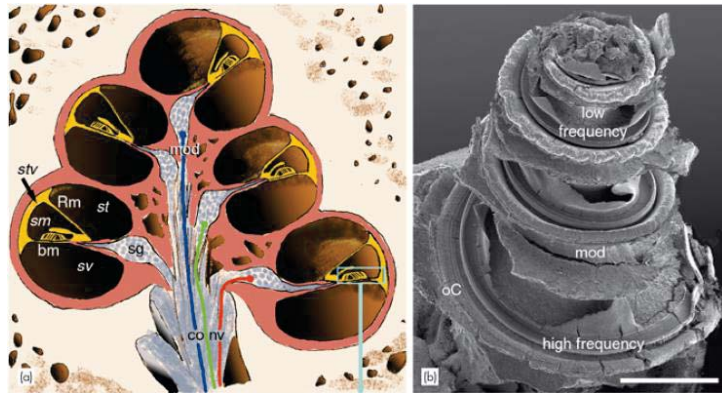
- o Also called vestibular membrane.
- o Roof of scala media.
- o Separates scala media from the scala vestibuli.
- o Two-cell layer membrane separated by a basement membrane:
- o Endothelial cell layer facing the scala media.
- o Mesothelial cell layer facing the scala vestibuli.

3. Stria vascularis:

- o Lateral wall of scala media.
- o Contains vascular epithelium.
- o Support cochlear function.
- o Na-K ATPase keeps membrane potential at **+80 mV**.
- o Secretes of **Endolymph**.



- **Ductus reuniens:** narrowest segment connects cochlear duct to the saccule.
- **Periotic duct:** located within the **cochlear aqueduct**, connects the scala tympani to the posterior cranial fossa.



- The central bony axis of the spiral, the modiolus (mod) contains the spiral ganglion (sg) comprised of bipolar neurones that peripherally innervate the hair cells and centrally form the cochlear nerve (co nv).
- Afferent fibres representative of **low** (blue), **middle** (green) and **high** (red) frequency illustrate the tonotopic arrangement within the nerve.

2. Saccul

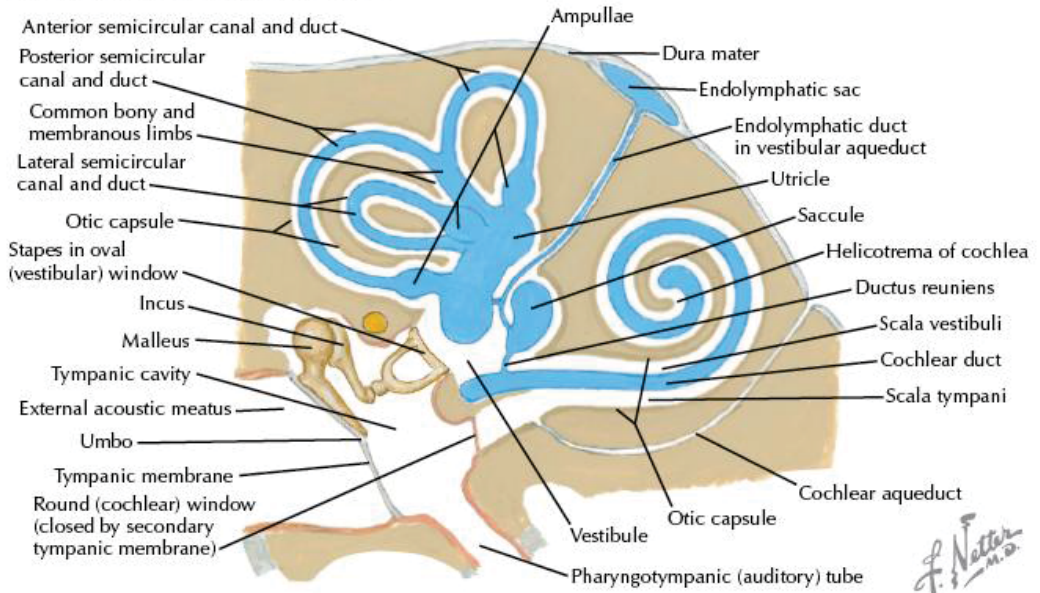
- Lies in the Anterior part bony vestibule.
- Anterior and perpendicular to the utricle and opposite the stapes footplate.
- Communicates with **Cochlear duct** (via **Ductus reuniens**).
- Communicates with **Endolymphatic duct** (via **Saccular duct**).
- Does NOT communicate directly with utricle
- Its sensory epithelium is called the **macula**.
- Saccular macula lies mostly in vertical plane.
- Detects Vertical linear acceleration and change in Gravity
- Can be surgically decompressed by perforating the stapes footplate in Meniere's disease.

3. Utricle

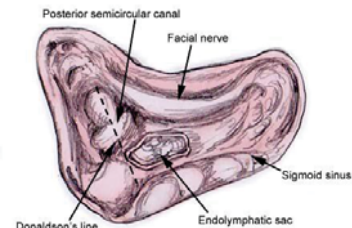
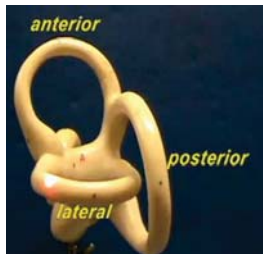
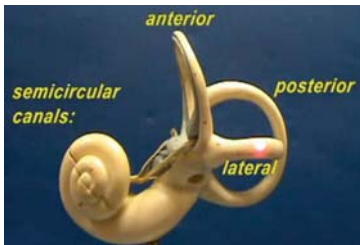
- Utricle lies in the Posterior part of bony vestibule.
- Parallel to earth and aligned with Lateral SCC.
- Superior to Saccul.
- Receives the five openings of the three semicircular ducts.
- Communicates with **Endolymphatic duct** (via **Utricular duct**).
- The sensory epithelium of the utricle is also called the **macula**.
- Macula utriculi lies mostly in horizontal plane.
- Detects Horizontal linear acceleration.

4. Semicircular ducts

- Three in number and correspond exactly to the three bony canals.
- Open in the utricle.
- Sensory receptors are located in the ampullated end and known as **Crista Ampullaris**, which contains hair cells.
- Concerned with for Angular acceleration.

Bony and membranous labyrinths: schema**5. Endolymphatic Duct and Sac**

- Endolymphatic duct:
 - Formed by the union of two ducts, one each from the saccule and the utricle.
 - Contained within the **vestibular aqueduct**.
 - Its terminal part is dilated to form endolymphatic sac which lies between two layers of dura on the posterior surface of petrous bone.
- Endolymphatic sac:
 - **Site of endolymph absorption.**
 - The 1st to appear and the last to stop growth.
 - Surgically important, it is exposed for drainage or shunt operation in Meniere's disease.
 -



Inner Ear Fluids and their Circulation

1. Perilymph :

- Within the bony labyrinth.
- Resembles Extracellular fluid (ECF) and CSF.
- Rich in **Na** ions. ($\text{Na} > \text{K}$)
- Contributes to electrical potential of **0 mV** in scala vestibuli and scala tympani.
- Formed from the filtrate of blood and diffusion of CSF.
- Communicates with CSF through the **aqueduct of cochlea** which opens into the scala tympani near the round window.
- In fact this duct is not a direct communication but contains connective tissue resembling arachnoid through which perilymph percolates.
- Changes in blood composition are reflected much more rapidly in perilymph than in CSF.
- Perilymph leaves the ear by drainage through venules and through the middle ear mucosa.

2. Endolymph

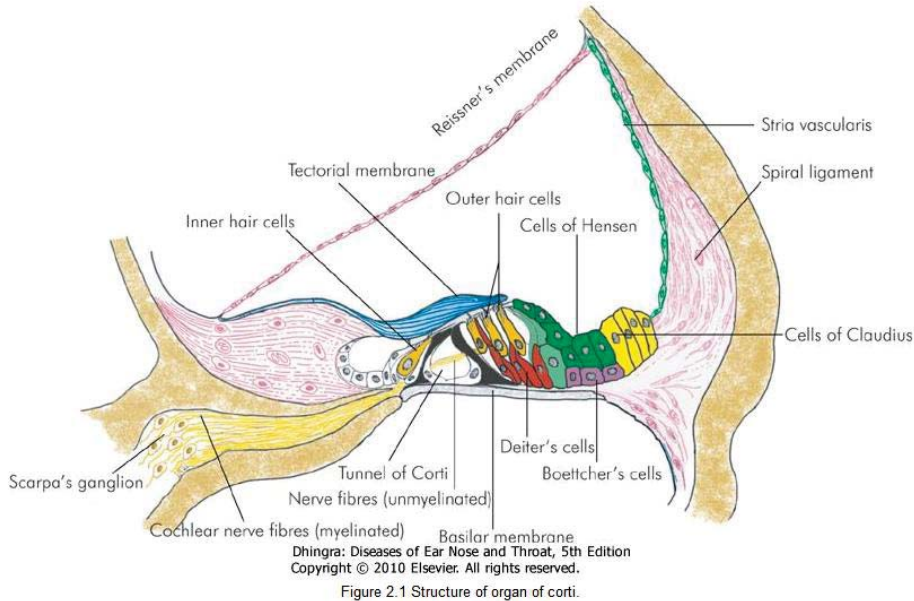
- Within the membranous labyrinth.
- Resembles Intracellular fluid (ICF).
- Rich in **K** ions. ($\text{K} > \text{Na}$)
- Contributes to positive DC resting potential of **+80 mV** in scala media also called cochlear duct.
- Secreted by the secretory cells of the stria vascularis of the cochlea and by the dark cells (present in the utricle and also near the ampullated ends of semicircular ducts).
- Gets absorbed through endolymphatic sac which lies in the subdural space.

Table 1-2. Composition of inner ear fluids

	Endolymph	Perilymph	CSF
Na ⁺ (mEq/L)	5	140	152
K ⁺ (mEq/L)	144	10	4
Protein (mg/dL)	126	200-400	20-50
Glucose (mg/dL)	10-40	85	70

Organ of Corti

- Sense organ of hearing.
- Situated on the basilar membrane of Scala media.



Important components of the organ of corti:

1. Tunnel of Corti

- o Formed by the inner and outer rods.
- o Contains a fluid called **cortilymph** (similar to Perilymph).
- o Exact function of the rods and cortilymph is not known.

2. Hair cells

- o Receptor cells of hearing.
- o Transduce mechanical sound energy into electrical energy.
- **Inner hair cells:**
 - o Principal transducer of motion from the basilar membrane to nerve impulse.
 - o Single row.
 - o Fewer in number.
 - o Rounded, Flask-like shape with nucleus in the center.
 - o Low intracellular glycogen.
 - o Few stereocilia in curvilinear shape.
 - o Loose connection to tectorial membrane.
 - o Completely surrounding by supporting cells.
 - o Afferent innervation: **Type I** (Radial, bipolar, myelinated), form 95% of fibers of the cochlear nerve.
 - o Each inner hair cell is innervated by 10-20 neurons (Low hair to ganglion ratio) --> cochlear nucleus.
 - o Efferent innervation: Sparse

➤ **Outer hair cells:**

- Cochlear amplifier which amplify motion from the basilar membrane.
- **Source of otoacoustic emissions.**
- 3 rows.
- More numerous.
- Cylindrical shaped with nucleus at base.
- High intracellular glycogen.
- Many stereocilia in "w" or "v" shape.
- Tight connection to tectorial membrane.
- Supported only at base.
- **Afferent innervation:** **Type II** (Spiral, pseudomonopolar, unmyelinated), form 5% of fibers of the cochlear nerve.
- Each 10 outer hair cells are innervated by one neuron (High hair to ganglion ratio) --> cochlear nucleus.
- **Efferent innervation:** from the auditory cortex down to the cochlear nuclei, additional contributions from the superior olive join and terminate predominantly on the outer hair cells.

3. Supporting cell

- Provide nutrients and structural support.
- **Deiters' cells** are situated between the outer hair cells and provide support to the latter.
- **Hensens' cells** lie outside the Deiters' cells.
- **Claudius' cells**

4. Tectorial membrane

- Fibrogelatinous structure
- Arises from the bony spiral lamina.
- Tips of stereocilia of the **outer hair cells** are **partially embedded** in the tectorial membrane.
- Vibration of the basilar membrane causes shearing forces at the tectorial membrane which then results in stimulation of the hair cells.

B. Section through turn of cochlea

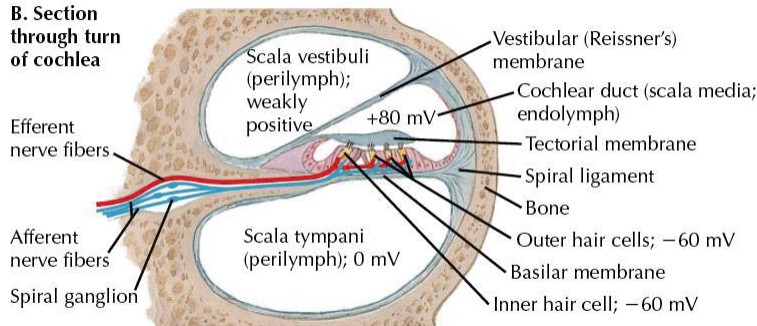


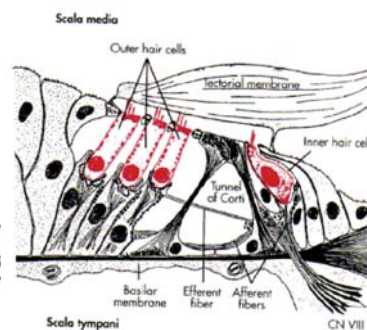
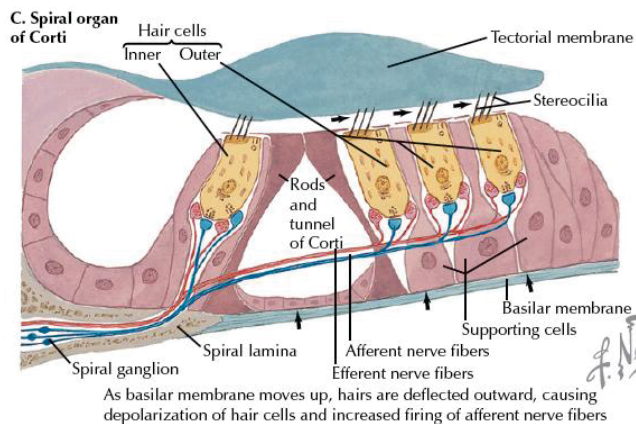
TABLE 129.1. STRUCTURE AND INNERVATION OF INNER AND OUTER HAIR CELLS

Characteristic	Inner Hair Cells	Outer Hair Cells
Number	3,500	12,000
Shape	Flask	Cylindrical
Stereocilia		
No. of hair cells	Few	Many
Arrangement	3 or 4 rows; rows slightly curved	6 or 7 rows; rows arranged in V or W shape
Attachment to tectorial membrane	None or loosely connected	Longest stereocilia firmly embedded
Ultrastructure		
Position of nucleus cell body	Center	Base
Cytoplasmic organelles	Scattered	Adjacent to cell membrane
Presynaptic specializations	Large	Small or absent (synaptic bars and vesicles)
Glycogen content	Low	High
Relation to supporting cells	Completely surrounded	Supported only at surface and base
Afferent innervation		
Ganglion cells	Type I	Type II
Number of ganglion cells	27,000	2,100
Hair cell to ganglion cell ratio	1.8:1	5.7:1
Efferent innervation		
Source	Lateral superior olivary complex	Medial superior olivary complex
Postsynaptic target	Afferent dendrites	Base of hair cell

From Neely JG, Dennis JM, Lippe WR. Anatomy of the auditory end organ and neural pathways. In: Cummings CW, ed. *Otolaryngology—head and neck surgery*. St. Louis: Mosby, 1986:2571, with permission.

Table 2-1. Differences between inner and outer hair cells

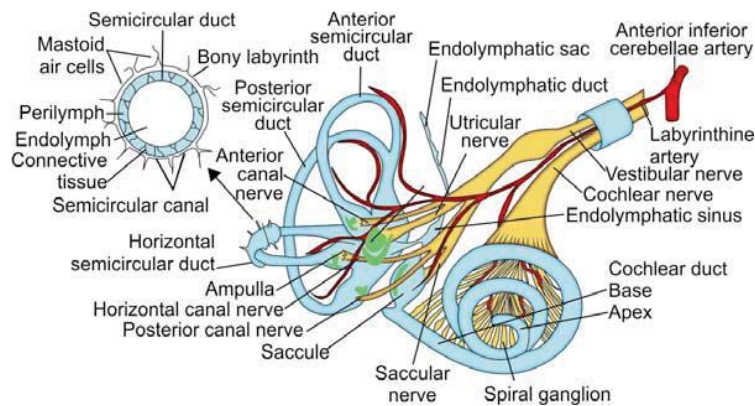
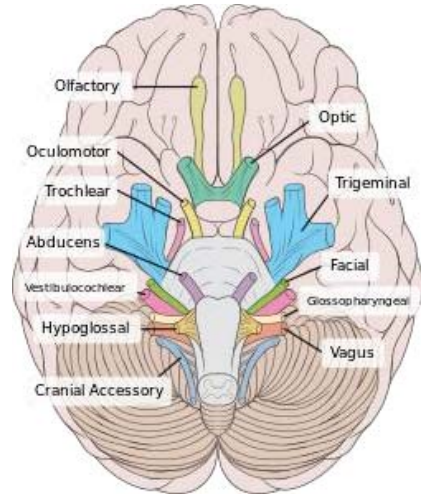
	Inner hair cells	Outer hair cells
Total no.	3500	12,000
Rows	One row	Three or four rows
Shape	Flask-shaped	Cylindrical
Nerve supply	Primarily afferent fibres and very few efferent	Mainly efferent fibres and very few afferent
Development	Develop earlier	Develop late
Function	Transmit auditory stimuli	Modulate function of inner hair cells
Vulnerability	More resistant	Easily damaged by ototoxic drugs and high intensity noise



- **Sensory Innervation of Inner Ear:**

- **Vestibulocochlear Nerve (CN VIII)**

- Emerges between the pons and medulla oblongata.
- Enters the internal acoustic meatus with the Facial nerve
- Divides into vestibular branches and the cochlear branch.
- In the internal auditory meatus, the vestibular and cochlear nerves merge.
- During their course to the brainstem, the Facial nerve becomes located further up the brain.
- A small arterial branch from the **Anterior Inferior Cerebellar Artery** (AICA) runs between the CN-VII and CN-VIII on the brainstem.
- It can be seen during vestibular schwannoma surgery and be used as a landmark.



- **Vestibular Nerve:**

- Nerve cell bodies are located in the vestibular ganglion (Scarpa's ganglion).
- Divides into superior and inferior branches.
 - o **Superior vestibular Nerve:**
 1. Ampulla of the **Superior** SSC.
 2. Ampulla of the **Lateral** SSC.
 3. Macula of the **Utricle**.
 4. The Antero-superior portion of macula of the saccule.
 - o **Inferior vestibular Nerve:**
 1. Ampulla of the **Posterior** SSC.
 2. Main portion of macula of the **Saccule**.

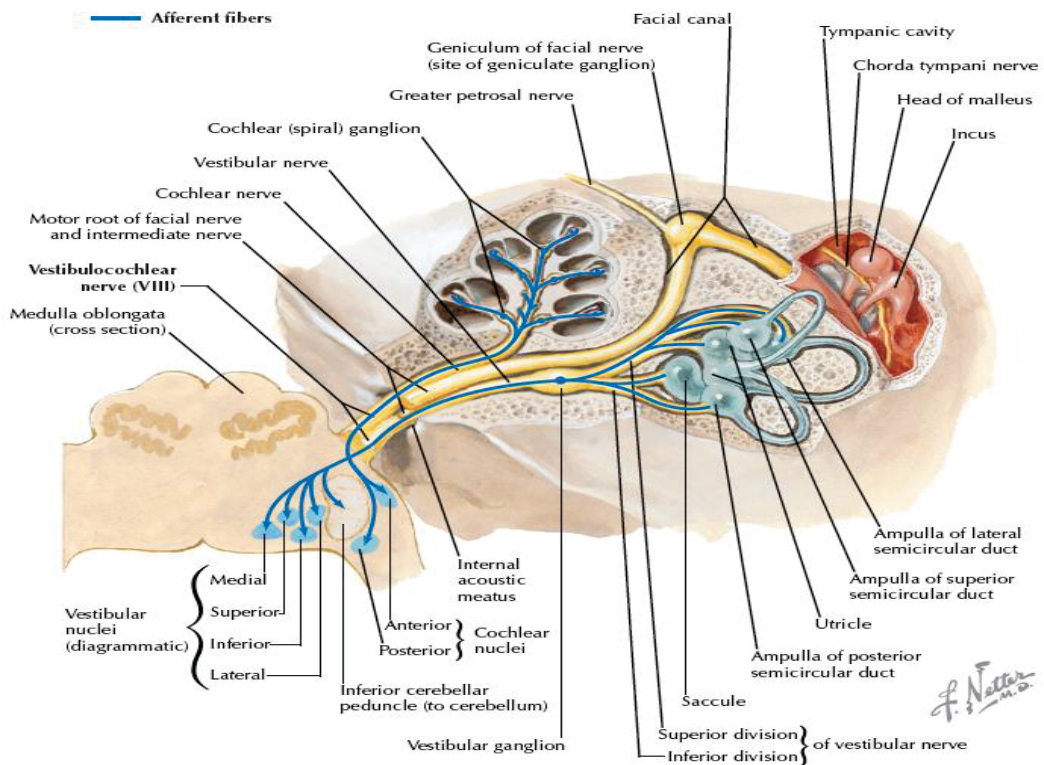
- **Auditory Sensory System:**

- **Cochlear Nerve:**

- Acoustic information from the hair cells is transferred by the Cochlear nerve to the ipsilateral cochlear nuclear complex in the brain stem.
- Cochlear nerve is composed of Afferent fibers from spiral ganglion neurones just central to the osseus spiral lamina.

- **Spiral ganglion:**

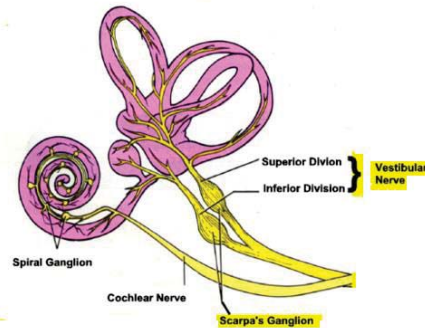
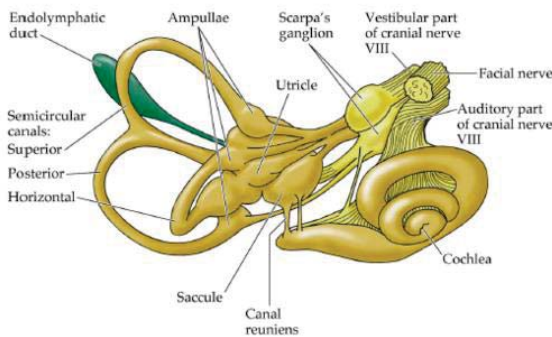
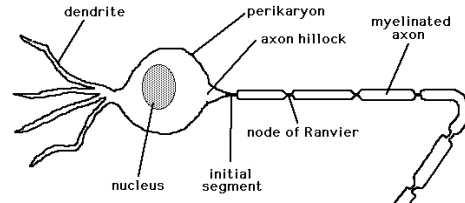
- Cell body of Cochlear nerve.
- Follows the course of the organ of Corti inside the modiolus.
- Sends two types of Afferent fibers type I that innervate the inner hair cells and type II that innervate the outer hair cells.
- Majority of spiral ganglion neurones (95%) are type I and innervate the inner hair cells.
- 50,000 neurons innervate cochlea
- **95% synapse directly on Inner hair cells (Type I neurons):**
 - Predominantly Afferent.
 - 10-20 of these neurons innervate each inner hair cells
- **5% synapse directly on Outer hair cells (Type II neurons):**
 - Predominantly Efferent.
 - Each type II neuron branches to innervate ~ 10 outer hair cells
- Efferent fibres to the hair cells come from the olivocochlear bundle. Their cell bodies are situated in superior olivary complex.
- Each cochlea sends innervation to both sides of the brain.



- **Vestibular Sensory System:**

- **Scarpa's ganglion:**

- Also called Vestibular ganglion.
- Cell body of vestibular nerve.
- Consists of bipolar neurons located in the lateral part of the internal auditory canal.
- Consists of superior and inferior group of cells associated with the superior and inferior vestibular nerve.
- Numbers of both vestibular hair cells and nerve cells in Scarpa's ganglion are found to be reduced in the ears of older people.
- Like the bodies of the human spiral ganglion, the perikarya of the vestibular ganglion cells are unmyelinated and surrounded by a thin sheath of Schwann cell.



- **Three distinct types of Vestibular Afferents**

1. **Calyx:**

- Terminate exclusively on **type I hair cells**
- May terminate on one or several hair cells
- Thicker axons
- Terminate in central zone of crista ampullaris and near striola
- Irregularly firing; sensitive to galvanic stim, not angular mov't

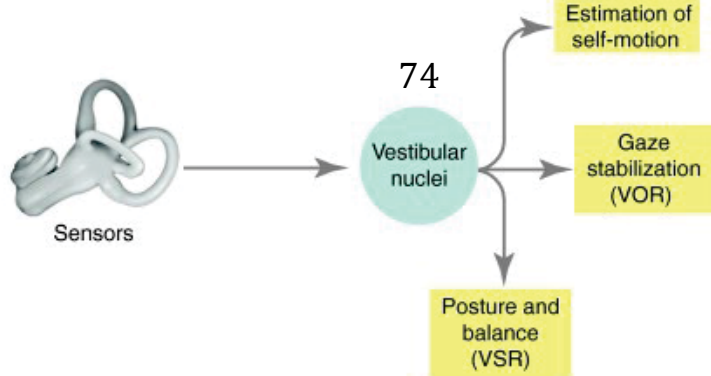
2. **Dimorphic:**

- Endings on **both** type I and type II hair cells
- Most prevalent (probably)
- Can be thin or thick
- Terminate in central, intermediate and peripheral zones
- Combo of both wrt sensitivity/firing; depends on location

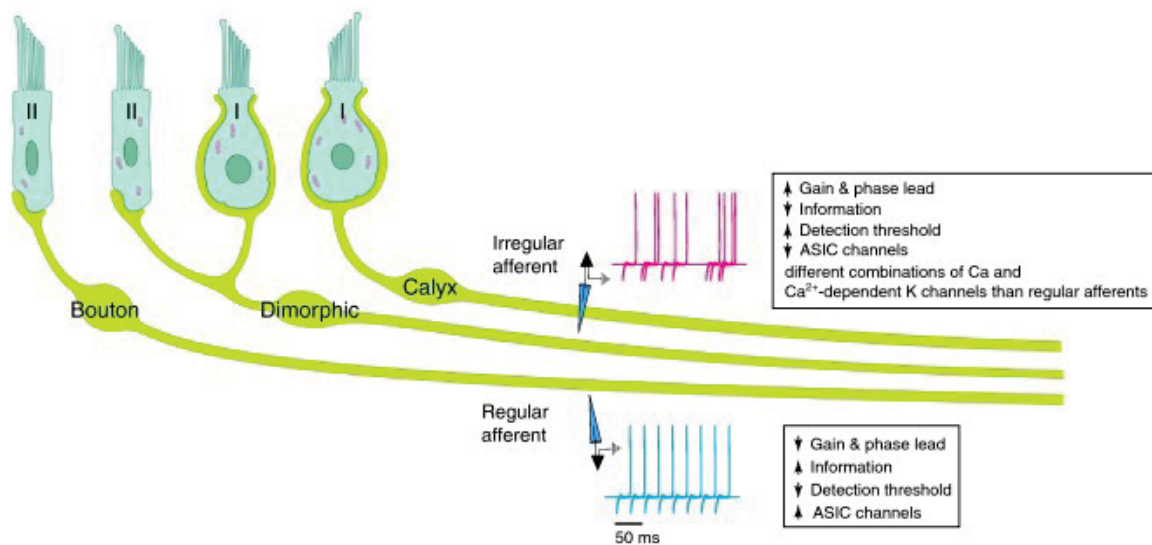
3. **Bouton:**

- Terminate only on **type II hair cells**
- Thinner axons
- Terminate in peripheral zone of crista ampullaris
- Lower galvanic and natural stim thresholds; regular firing with slower conduction velocities.

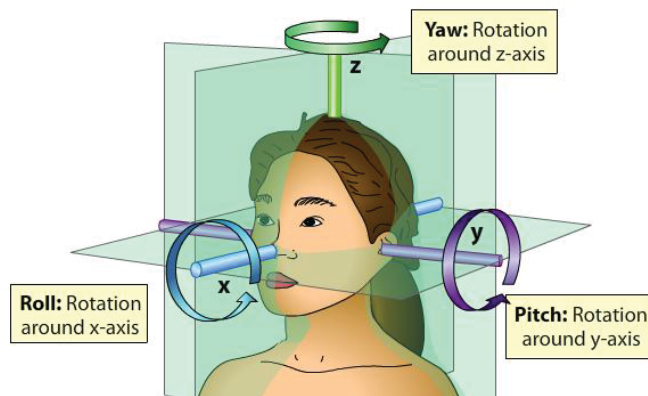
(a)



(b)



- All vestibular epithelium has efferent fibres; function unknown.
- The vestibular system plays a Lesser role for the control of human posture and balance.
- The main peripheral component of the vestibular system is the labyrinth.
- Labyrinth has sensory cells known as Hair cells that transduce physical motion into neural impulses.
- Motions in the labyrinth are due to:
 - o Head movements
 - o Inertial effects due to gravity
 - o Ground-borne variations
- Labyrinth consists of:
 - o 2 otolith organs (Utricle and Sacculle)
 - o 3 SCC.
- Utricle and sacculle are specialized primarily to respond to:
 - o Linear accelerations of the head.
 - o Static head position relative to the gravitational axis
- SCC are specialized for responding to:
 - o Rotational accelerations of the head in 3 planes.



- **Neuroepithelium of Vestibular system:**
- Composed of sensory hair cells in contact with a gelatinous membrane.
- Hair cell bundles in each vestibular organ have specific orientations.
- The organ as a whole is responsive to displacements in ALL directions.
- **Glutamine** is the neurotransmitter.
- There are now data suggesting that the sensory vestibular epithelia may regenerate in mammals including man, which may explain the return of symptoms after gentamicin treatment in patients with Meniere's disease.

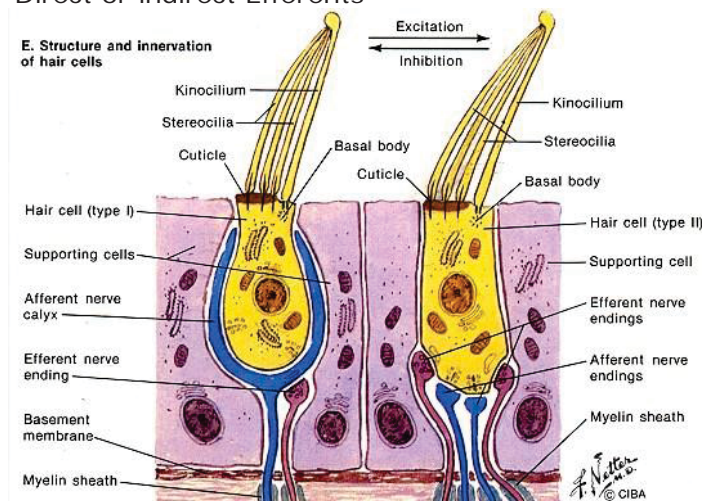
- Two types of sensory hair cells:

1. Type I:

- o Flask-shaped.
- o Surrounded by **one** nerve **Chalice** (cup or goblet) formed by the terminal end of the **Afferent nerve** fiber of the vestibular nerve.
- o Correspond to the inner hair cells of the organ of Corti.
- o Stereocillia & kinocilium arrangement.

2. Type II:

- o Cylindrical in shape.
- o Same arrangement of stereocillia & kinocilia as the type I cells.
- o One or **more Afferents**
- o Direct or indirect Efferents



- Hair cell arrangement:

- The upper surface of the hair cell contains approximately 70 stereocilia and one kinocilium arranged with the longest stereocilia positioned adjacent to the kinocilium.
- The upper surface of the cell contains a thicker region, called the '**Cuticular plate**', into which the stereocilia extend their rootlets.

1. Kinocilium:

- o Tallest.
- o Near edge of top hair cell
- o A true cilium demonstrating the 9 + 2 arrangement of microtubules.

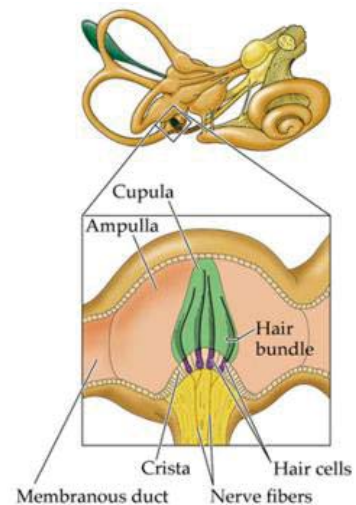
2. Stereocilia:

- o Arranged in rows.
- o Stereocilia closer to kinocilia are longer.

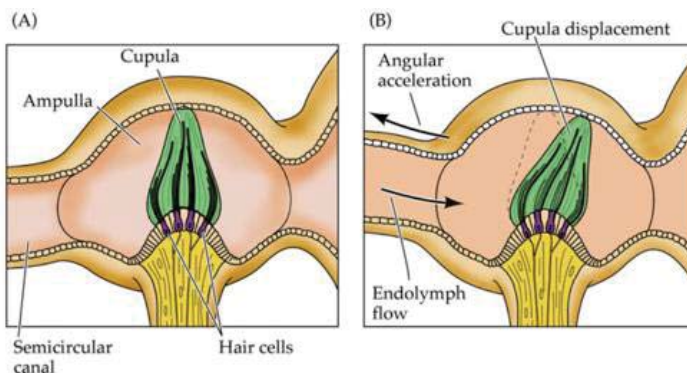
- Deflection of stereocilia **TOWARD** the kinocilium results in **Increased** vestibular neuronal firing rate.
- Deflection of stereocilia **AWAY** from the kinocilium results in **Decreased** vestibular neuronal firing rate.
- Hair cells in utricle and saccule act similarly to SCC in regard to the kinocilia and stereocilia, however, the utricle and saccule's hair cells are arranged in a specific pattern.
- Sensory Hair cells are found in:
 1. **Ampullae of SCCs.**
 2. **Macula of Otolith organs (utricle and saccule).**

- **Ampullae of SCC:**

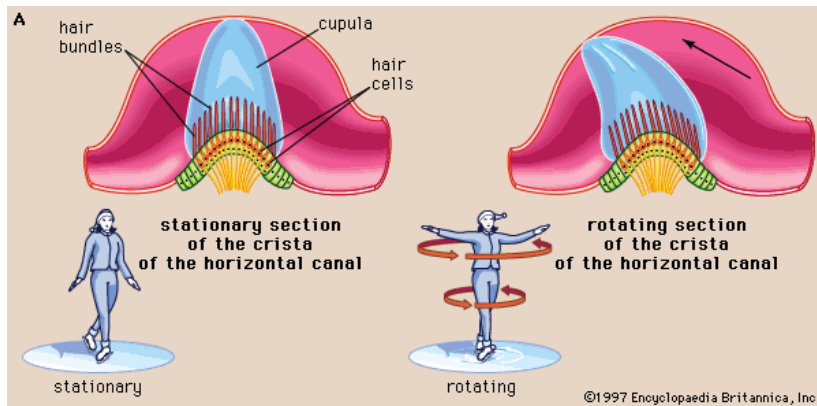
- Ampullae are bulbous expansion located at the base of SCC next to the utricle.
- Houses the sensory epithelium known as **Crista** that contains the hair cells
- Hair bundles extend out of the crista into a gelatinous mass known as the **Cupula**.
- Cupula bridges the width of the ampulla, forming a viscous barrier through which endolymph cannot circulate.
- The relatively compliant cupula is distorted by movements of the endolymph.
- When the head turns in the plane of one of the semicircular canals, the inertia of the endolymph produces a force against the cupula, distending it away from the direction of the head movement.



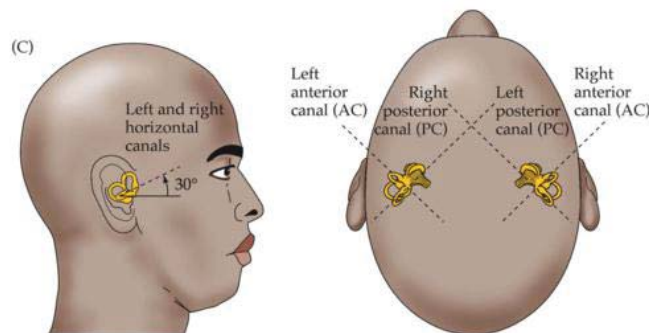
- Distention of the cupula away from the direction of head movement causes a displacement of the hair bundles within the crista.
- Linear accelerations of the head produce **EQUAL** forces on the 2 sides of the cupula, so the hair bundles are **NOT** displaced



- SCC sense Head rotation either arising from self induced movements or from angular accelerations of the head imparted by external forces.
- Unlike the saccular and utricular maculae, ALL hair cells in the crista within each SCC are organized with their kinocilia pointing in the SAME direction.
- When the cupula moves in the **Appropriate direction**, the entire population of hair cells is **Depolarized** and the activity in ALL of the innervating axons is **Increased**
- When the cupula moves in the **Opposite direction**, the population is **Hyperpolarized** and neuronal activity **Decreases**.

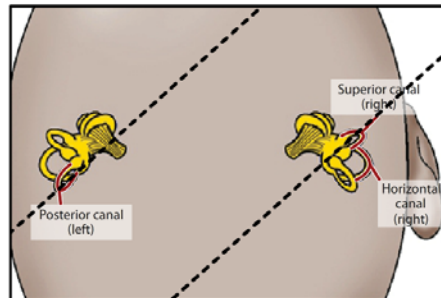


- The specific gravity of the cupula is approximately 1.0, which is same as that of the Endolymph.
- This matching of the specific gravity is necessary to prevent the cupula from floating upward in certain head positions and causing an enduring nystagmus.
- Disruption of this match in specific gravity is likely the cause of **Postalcoholic Nystagmus**.

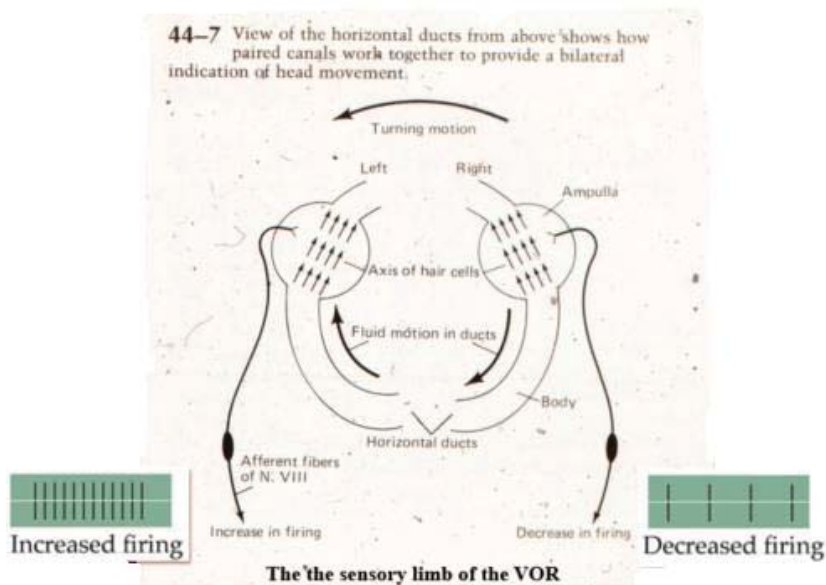


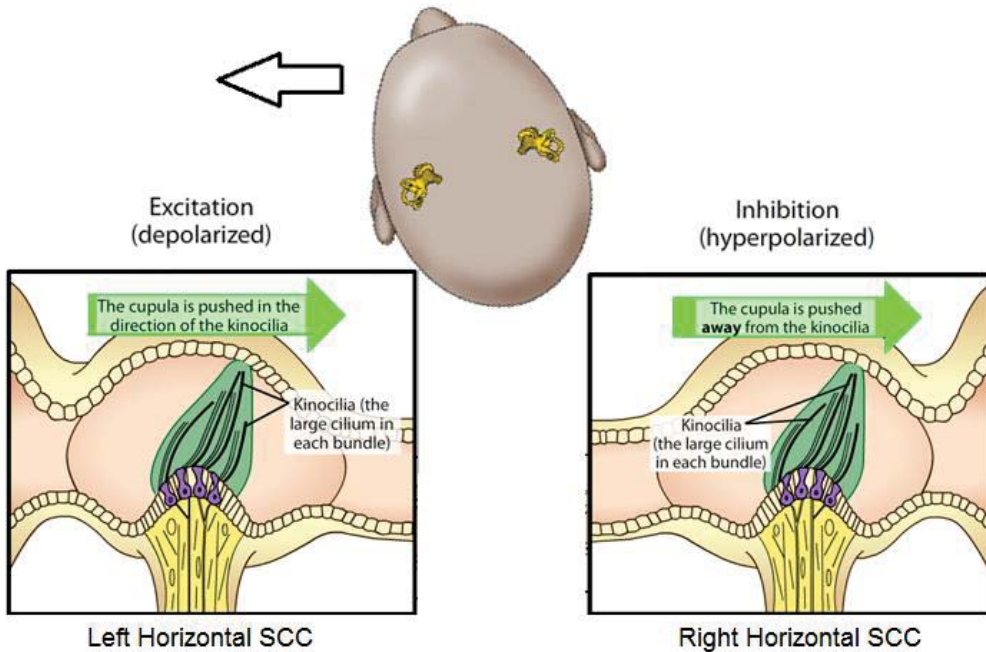
- Each semicircular canal works in concert with the partner located on the other side of the head that has its hair cells aligned oppositely.

- Three pairs:
 - o 2 pairs of horizontal canals
 - o Superior canal on each side working with the Posterior canal on the other side, both are in same plane.



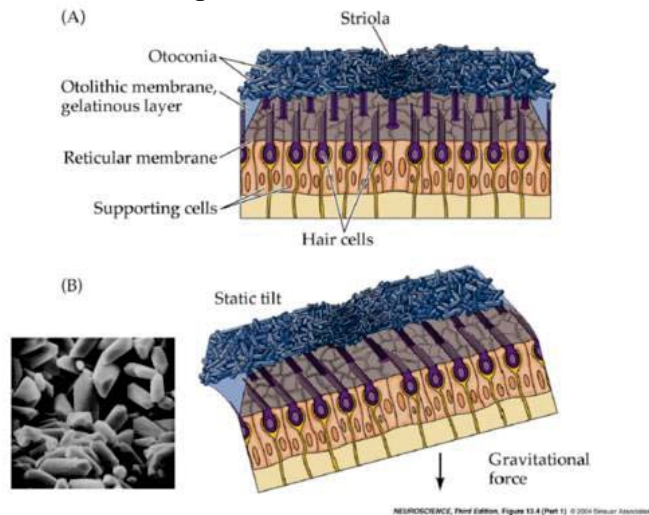
- Head rotation deforms the cupula in opposing directions for the 2 partners, resulting in opposite changes in their firing rates.
- Orientation of the horizontal canals makes them selectively sensitive to rotation in the horizontal plane.
- Hair cells in the canal Toward which the head is turning are Depolarized, while those on the other side are Hyperpolarized.



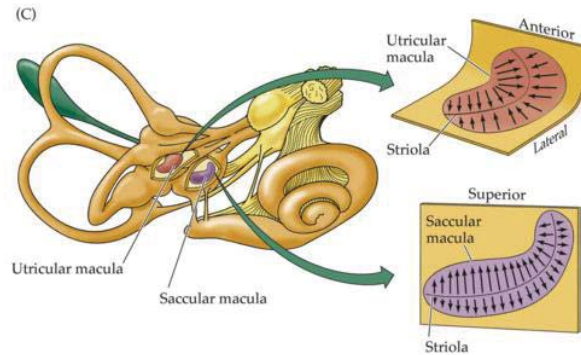


- **In Horizontal SCC:**
 - Kinocilia are located on the Utricular side.
 - Afferents are stimulated when endolymph flows against the utricle.
 - Displacement of stereocilia **TOWARD** the Utricle (**AmpulloPetal**) causes **Increased** vestibular neuronal firing rate (depolarization).
 - Displacement of stereocilia **AWAY** from the Utricle (**AmpulloFugal**) causes **Decreased** vestibular neuronal firing rate (Hyperpolarization).
- **In Vertical SCC (Posterior and Superior):**
 - Kinocilia are located on the Semicircular canal side.
 - Afferents are stimulated when endolymph flows against the Ampulla.
 - Displacement of stereocilia **TOWARD** the Utricle (**AmpulloPetal**) causes **Decreased** vestibular neuronal firing rate (Hyperpolarization).
 - Displacement of stereocilia **AWAY** from the Utricle (**AmpulloFugal**) causes **Increased** vestibular neuronal firing rate. (depolarization).

- **Macula of Otolith organs**
- Both the Saccule and Utricle contain a thickened sensory epithelium called Macula.
- Macula consists of :
 - Hair cells
 - Supporting cells
- **Gelatinous layer:**
 - Overlying the hair cells and their hair bundles.
- **Otolithic membrane:**
 - Fibrous structure above the gelatinous layer.
- **Otoconia:**
 - Also called Statoconia.
 - Calcium crystals containing material consisting of a multitude of small cylindrical and hexagonally shaped bodies with pointed ends
 - Anchored and partially embedded in the otolithic membrane.
 - Make the otolithic membrane heavier than the structures and fluids surrounding it.

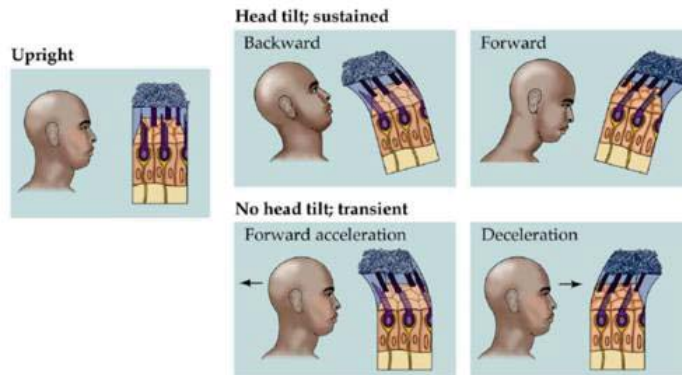
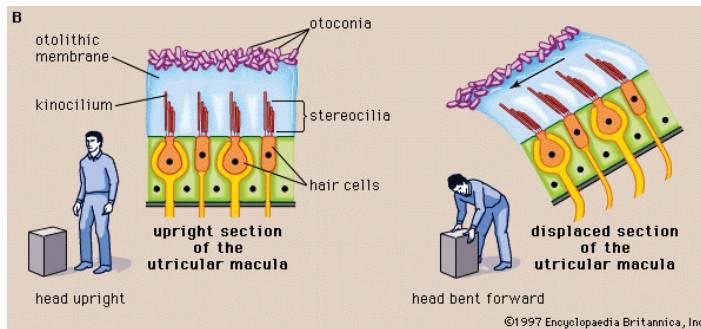


- Because of the heaviness by the otoconia, when the head tilts, gravity causes the membrane to shift relative to the sensory epithelium.
- The resulting shearing motion between the otolithic membrane and the macula displaces the hair bundles, which are embedded in the lower gelatinous surface of the membrane.



- **Striola:**
 - o Specialized area in the utricle and saccule.
 - o Divides the hair cells into 2 populations with **OPPOSING** polarities.
 - o Contain more Type I cells.
 - o Forms an axis of mirror symmetry such that hair cells on opposite sides of the striola have opposing morphological polarizations.
 - o A tilt along the axis of the striola will excite the hair cells on one side while inhibiting the hair cells on the other.
 - o Polarization of hair cells occurs point **TOWARD** striola in the **Utricular macula** and **AWAY** from the striola in the **saccular macula**.
- **Saccular macula:**
 - o Oriented in the **VERTICAL** plane.
 - o Detects Vertical linear acceleration and change in Gravity.
 - o Ex: Up/down and forward backward movements in the sagittal plane.
 - o Polarization of hair cells occurs point **AWAY** the striola.
- **Utricular macula:**
 - o Oriented in the **HORIZONTAL** plane.
 - o Detects Horizontal linear acceleration.
 - o Ex: Sideways head tilts and rapid lateral displacements would be detected by the utricle.
 - o Polarization of hair cells occurs point **TOWARD** the striola.
- Structure of the otolith organs enables them to sense both **Static** and **Transient** displacements.
- Tilting the head relative to the gravitational axis would be a **Static** displacement sensed by the otolith organs
- Translational movements of the head would be a **Transient** displacement sensed by the otolith organs.

- Note that the maculae respond only to changes in acceleration or velocity of head movement, they do NOT report on unchanging head positions.



- Other cell types of Macula:

1. Supporting cells:

- o Secrete Extracellular macromolecules of cupula and otolith membrane.

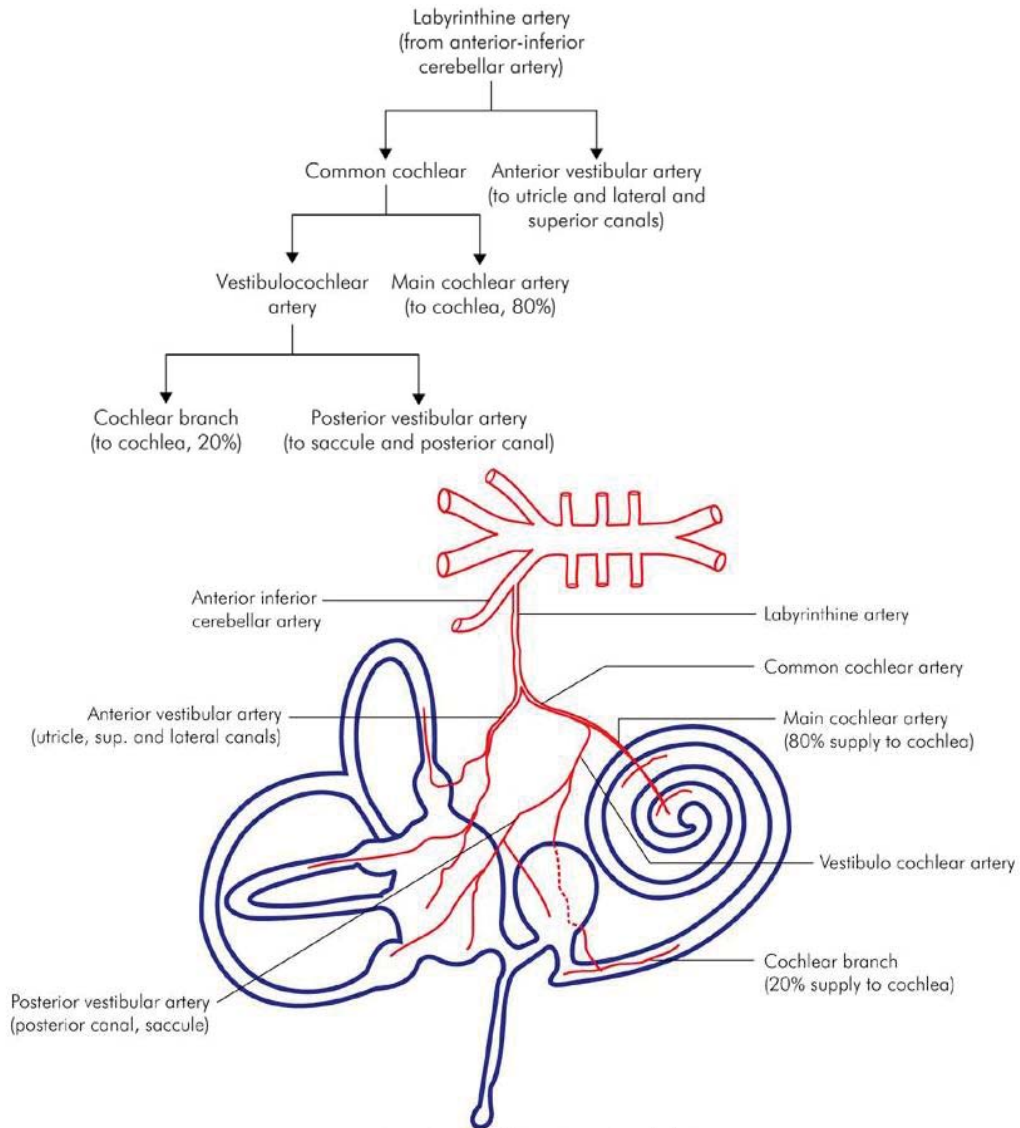
2. Dark cells:

- o Found in all sensory epithelia of membranous labyrinth, except the saccule which is believed to lack production of endolymph.
- o Produce ionic composition of **Endolymph**.
- o Involved in the degradation and resorption of dislodged otoconia.

- **Blood Supply of Inner Ear:**

- **Labyrinthine artery**

- o Supplies the entire labyrinth.
- o Branch of the Anterior inferior cerebellar artery (AICA) (**85%-100% cases**) or Basilar artery (**<15% cases**).
- o Accompanies the vestibulocochlear nerve through the internal acoustic meatus.
- o Divides into cochlear and vestibular branches that supply the cochlear and vestibular structures



- **Anterior Vestibular Artery:**
 - o Superior portion of Utricle and Sacule
 - o Superior and Horizontal SCC.
- **Posterior Vestibular Artery:**
 - o Inferior portion of Utricle and Sacule
 - o Posterior SCC.
- **Main Cochlear Artery:**
 - o ALL cochlea except One-Third of Basal turn.
- **Cochlear Branch:**
 - o One-Third of Basal turn.

- Venous drainage is through three veins, namely **internal auditory vein**, **vein of cochlear aqueduct** and **vein of vestibular aqueduct** which ultimately drain into inferior petrosal sinus and lateral venous sinus.
- Blood supply to the inner ear is independent of blood supply to middle ear and bony otic capsule, and there is no cross circulation between the two.
- Blood supply to cochlea and vestibular labyrinth is segmental, therefore, independent ischemic damage can occur to these organs causing either cochlear or vestibular symptoms.
- NO LYMPHATIC DRAINAGE OF INNER EAR.

Eustachian Tube Anatomy:

- Pharyngotympanic Tube.
- A dynamic channel that links Middle ear with Nasopharynx.
- Derived from **1st Pharyngeal Pouch**.
- In Adults:
 - o 36 mm in length
 - o Reach adult size at age 7.
 - o Runs downwards, forwards and medially from its tympanic end.
 - o Forming an angle of 45° with the horizontal.

- Divided into two parts:

1. Bony Part:

- o Lateral 1/3.
- o 12 mm in length.
- o Runs through Squamous and Petrous part of Temporal bone.
- o Thin plate of bone forms the Roof, separating ET from Tensor Tympani muscle above.
- o Carotid canal lies Medially and can impinge on Bony ET.
- o In cross section, ET is Triangular or rectangular with the horizontal diameter being the greater.
- o Tympanic End of ET:
 - At the Lateral end of the Bony part.
 - Oval in shape
 - Measures 5×2 mm.
 - Situated in Anterior wall of Middle Ear, above level of floor.
- o Isthmus:
 - Narrowest part of ET.
 - 0.5 mm in Diameter.
 - At Junction of Bony part and Fibrocartilaginous part.

2. Fibrocartilaginous Part:

- o Medial 2/3.
- o 24 mm in length.
- o Made of a single piece of cartilage folded upon itself.
 - Forms the Medial lamina, Roof and a part of Lateral lamina.
 - Rest of Lateral lamina is made of Fibrous membrane.
- o Nasopharyngeal End of ET:
 - At the Medial end of the Fibrocartilaginous part.
 - Slit-like, vertically.
 - The cartilage at this end raises an elevation called Torus Tubarius:
 - Situated in Lateral wall of Nasopharynx.
 - 1-1.25 cm behind Posterior end of Inferior Turbinate.

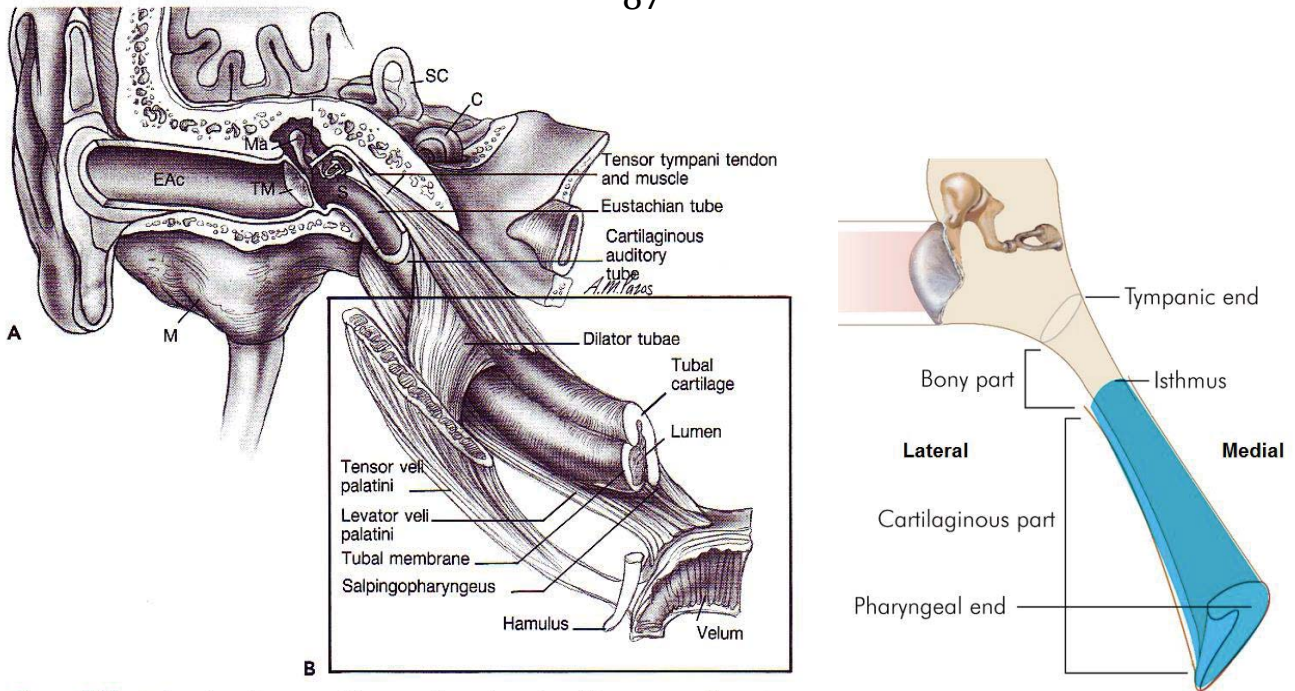
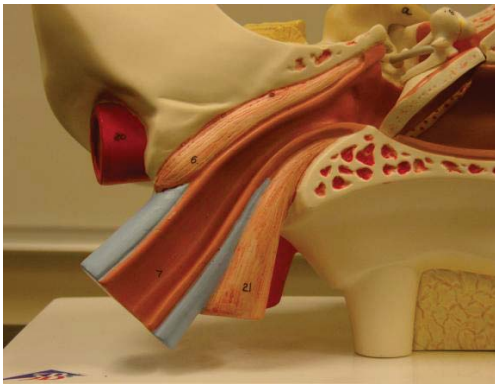


Figure 90.2 A: Complete dissection of the eustachian tube and middle ear. Especially evident are the relations between the eustachian tube, paratubal muscles, and cranial base, as well as the position of the juncture between the osseous portion of the eustachian tube and the middle ear. B: Relation between the superficial muscle bundle (tensor veli palatini) and the deep bundle (dilator tubae) to the lateral wall of the eustachian tube. C, cochlea; EAC, external auditory canal; I, incus; M, mastoid; Ma, malleus; S, stapes; SC, semicircular canals; TM, tympanic membrane.



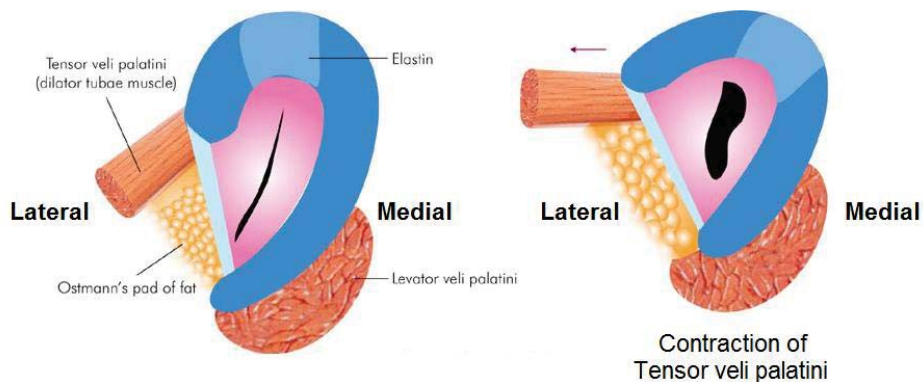
- **Lining of Eustachian Tube:**

- Pseudostratified ciliated columnar epithelium with mucous secreting goblet cells (**Respiratory Mucosa**).
- At Nasopharyngeal end of ET, the mucosa is truly respiratory; but in passing along the tube towards Middle ear, Number of goblet cells and glands decreases, and the ciliary carpet becomes less profuse.
- Cilia beat in the direction of Nasopharynx and helps to drain secretions and fluid from Middle ear into Nasopharynx.
- Submucosa of Cartilaginous part of ET is rich in seromucinous glands.

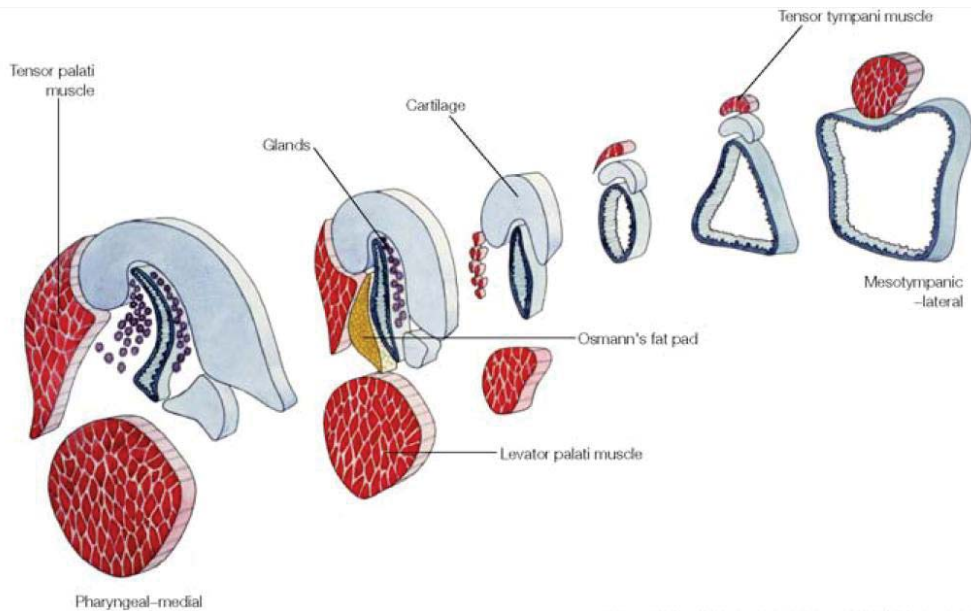
- **Muscles Related to Eustachian Tube:**

1. Tensor veli palatini.
2. Levator veli palatini.
3. Tensor Tympani.
4. Salpingopharyngeus.

MUSCLE	ORIGIN	INSERTION	NERVE SUPPLY	ACTION
Tensor Veli Palatini (Dilator Muscle)	Spine of Sphenoid. Eustachian Tube.	Forms the Palatin Aponeurosis with Tensor Veli Palatini from other side.	Nerve to Medial Pterygoid from Mandibular Branch (V3) of Trigeminal Nerve CN-V	<u>Medial fibers</u> are attached to Lateral lamina of ET. Contracts to open ET lumen. Tenses soft palate
Levator Veli Palatini	Petrous part of Temporal bone. Eustachian Tube.	Palatin Aponeurosis	Pharyngeal Plexus (Vagus Nerve CN-X)	Assist in opening ET. Raises the Palate.
SalpingoPharyngeous	Eustachian Tube.	Blends with PalatoPharyngeous.	Pharyngeal Plexus (Vagus Nerve CN-X)	Assist in opening ET. Elevates Pharynx.
Tensor Tympani	Wall of ET and wall of Its own canal.	Neck of Malleus.	Mandibular Branch (V3) of Trigeminal Nerve CN-V	Dampens down Vibrations of TM.



- **Elastin Hinge:**
- Elastin fibers found in junction of Medial and Lateral lamina at the Roof of Cartilaginous part of ET.
- Keeps ET closed by its recoil, when no longer acted upon by Tensor Veli Palatini (**Dilator Muscle**).
- **Ostmann's Fat Pad:**
- Mass of fatty tissues related **Laterally** to Membranous part of Cartilaginous tube.
- Keeps ET closed and protect it from reflux of Nasopharyngeal secretions.



- **Arterial blood supply of ET:**
- 1. Ascending Pharyngeal Artery.
- 2. Middle Meningeal Artery.
- **Venous blood drainage of ET:**
- Pharyngeal plexus
- **Lymphatics drainage of ET:**
- Retropharyngeal nodes.
- **Nerve Supply of ET:**
- Tympanic branch of **CN-IX:**
 - o Sensory and Parasympathetic Secretomotor Fibers to ET mucosa.

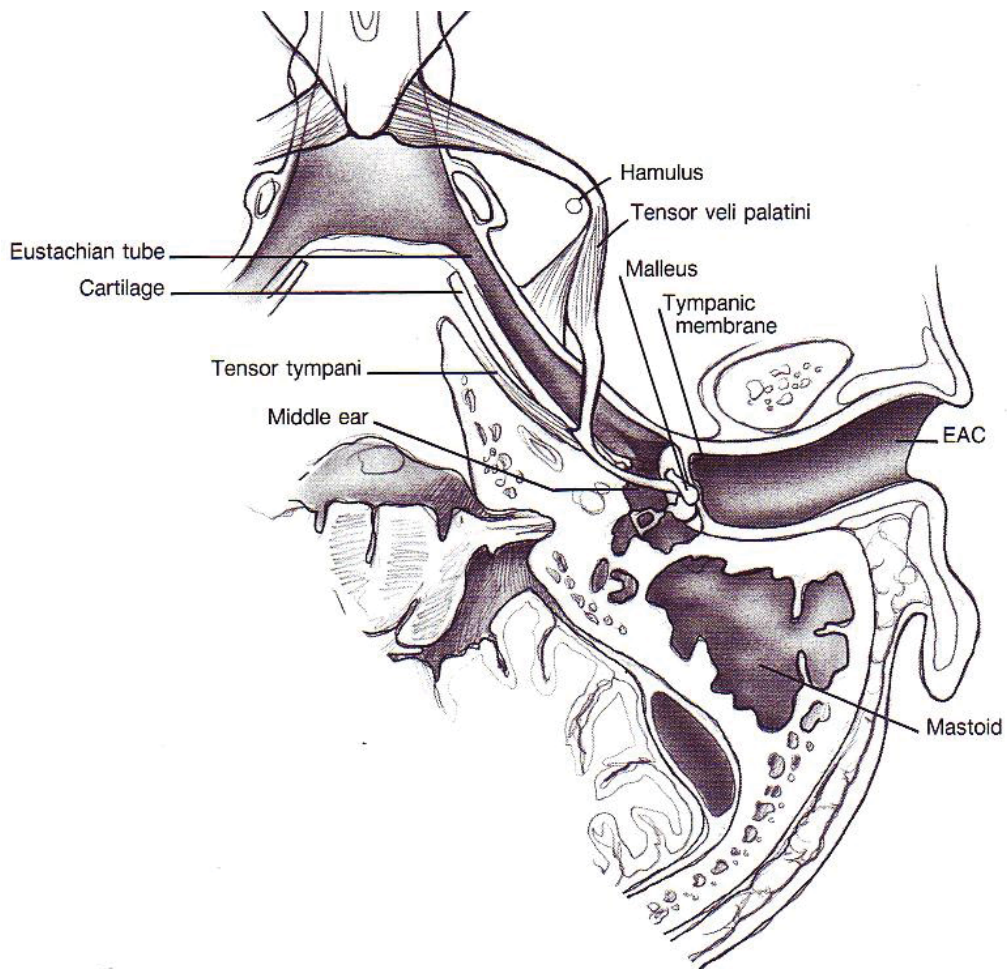


Figure 90.3 Drawing shows the tensor veli palatini muscle attachment along the lateral wall of the eustachian tube, including its course around the hamulus of the pterygoid bone and its attachment into the posterior margin of the hard palate. EAC, external auditory canal.

- **Eustachian Tube in Infants:**
 - Shorter.
 - Wider.
 - More Horizontal.
 - More susceptible to regurgitation from Nasopharynx into Middle Ear with feeding.

Table 9-1. Differences between infant and adult eustachian tube

	Infant	Adult
Length	13-18 mm at birth (about half as long as in adult)	36 mm (31-38 mm)
Direction	More horizontal. At birth it forms an angle of 10° with the horizontal At age 7 and later it is 45°	Forms an angle of 45° with the horizontal
Angulation at isthmus	No angulation	Angulation present
Bony versus cartilaginous part	Bony part is slightly longer than 1/3 of the total length of the tube and is relatively wider	Bony part 1/3; cartilaginous part 2/3
Tubal cartilage	Flaccid. Retrograde reflux of nasopharyngeal secretions can occur	Comparatively rigid. Remains closed and protects the middle ear from the reflux
Density of elastin at the hinge	Less dense; tube does not efficiently close by recoil	Density of elastin more and helps to keep the tube closed by recoil of cartilage
Ostmann's pad of fat	Less in volume	Large and helps to keep the tube closed

- **Movement of ET:**
 1. Passive closure by:
 - Elastic Recoil.
 - Passive pressure from surrounding tissue.
 2. Active opening by:
 - Tensor veli platini muscle.
- **Main Functions of Eustachian Tube:**
 1. Ventilation and Regulation of Middle Ear Pressure.
 2. Protection against:
 - Nasopharyngeal sound pressure.
 - Reflux of Nasopharyngeal secretions.
 3. Middle Ear clearance and drainage of secretions.
- **Ventilation and Regulation of Middle Ear Pressure:**
 - For Normal hearing:
 - Pressure on two sides of TM should be Equal.
 - Negative or Positive Pressure in Middle ear affects hearing.
 - ET should open periodically to equilibrate Air pressure in Middle ear with Ambient pressure.
 - Normally, ET remains closed and opens intermittently during:
 - Swallowing
 - Yawning
 - Sneezing
 - ET opening function is Poor in:
 - Recumbent position and during sleep due to Venous Engorgement.
 - Infants and Young children.

- **Protective Functions:**

- High sound pressures from Nasopharynx can be transmitted to Middle ear if Tube is open and interfering with normal hearing (**Patulous Eustachian Tube**)
- ET remains closed normally and protects Middle ear against these sounds.
- ET also protects from reflux of Nasopharyngeal secretions into the Middle ear.
- This reflux occurs more readily if:
 - o ET is wide in diameter (patulous tube).
 - o Short in length, (infants).
 - o Perforated TM (cause for persistence of middle ear infections).
 - o High pressures in Nasopharynx (Forceful nose blowing, closed-nose swallowing as in adenoid hypertrophy or bilateral nasal obstruction)

- **Clearance of Middle ear secretions:**

- Mucous membrane of ET and Anterior part of Middle ear is lined by Ciliated columnar cells.
- Cilia beat in direction of Nasopharynx to clear secretions and debris in Middle ear.
- Clearance function is further augmented by active opening and closing of the tube.

- **Eustachian Tube Function Tests**

1. Valsalva Test.
2. Toynbees's Test
3. Tympanometry

- **Valsalva Test:**

- Principle:

- o To build positive pressure in Nasopharynx so that Air enters ET into Middle ear.

- Method:

- o Exhalation against a closed airway.
- o Closing the Mouth and pinching the Nose.

- Results:

- o Normally:
 - Air enters Middle ear through ET.
 - TM move outwards (by Otoscope).
- o TM perforation:
 - Hissing sound is produced.
- o Failure of this test does not prove blockage of ET because only 65% of persons can successfully perform this test.

- Contraindications:

- o Presence of atrophic scar in TM which can rupture.
- o Presence of infection of Nose and Nasopharynx (Risk of Reflux).



- **Toynbee's Test:**
- **Principle:**
 - To build Negative pressure in Nasopharynx so that Air enters ET From Middle ear.
- **Method:**
 - Swallowing with pinched Nose.
- **Results:**
 - Normally:
 - Air enters Nasopharynx from Middle ear through ET.
 - TM move inwards (by Otoscope).
- **Tympanometry (Inflation-deflation Test):**
- **Principle:**
 - Normal ET is able to equilibrate Middle ear and Ambient pressure.
- **Method:**
 - Positive and Negative pressures (-200 or +200 mm of H2O) are created in EAC.
 - Patient swallows repeatedly (5 times in 20 seconds).
- **Results:**
 - Normally:
 - Equilibration of positive and negative pressures to Ambient pressure.
 - Done both in patients with perforated or intact TM.
 - Can be used to find the patency of VT.
- **Disorders of Eustachian Tube (ET)**
- **ET Obstruction:**
- Normally, ET is closed.
- Opens intermittently during swallowing, yawning and sneezing due to contraction of Tensor veli palatini muscle.
- Air (O₂, Co₂, Nitrogen, Water vapour) normally fills Middle ear and Mastoid.
 - Lower O₂ & CO₂ and higher N₂ compared to Atmosphere.
 - Similar to venous gas.
- **If ET is Blocked:**
 - Initially, Oxygen is Absorbed then other gases are Absorbed.
 - → Negative pressure in Middle ear.
 - → Retraction of TM.
 - → If Negative pressure is increased
 - → ET will be locked.
 - → Collection of Transudate and later Exudate.
 - → Atelectatic ear / Perforation.
 - → Retraction pocket / Cholesteatoma.
 - → Erosion of Incudo-Stapedial joint.

- **Causes of ET Ostruction**

1. URTI.

2. Allergy.

3. Sinusitis.

4. DNS.

5. Hypertrophic Adenoid:

- Mechanical obstruction of ET.
- Reservoir for Pathogenic organisms.
- Adenoidectomy helps with OME and Recurrent AMO.

6. Nasopharyngeal Tumor/mass.

7. Cleft Palate:

- Abnormalities of Torus Tubarius (High elastin density making tube difficult to open).
- Tensor veli palatini muscle does not insert into Torus tubarius in 40% cases of cleft palate.
- OME is common even after cleft palate repair.
- Requires insertion of VT.

8. Down's syndrome.

- Poor tone of Tensor Veli Palatini muscle.
- Abnormal shape of Nasopharynx.
- OME is common.
- Requires insertion of VT.

- **Signs and Symptoms of ET Obstruction:**

- Otalgia, CHL, Popping sensation, Tinnitus and Vertigo.
- Retracted TM, Congested TM, Transudate behind TM imparting it an Amber colour and a Fluid level.

- **Retraction Pockets and ET:**

- Air passes from ET to Mesotympanum, Attic, Aditus, Antrum and Mastoid air cell system.

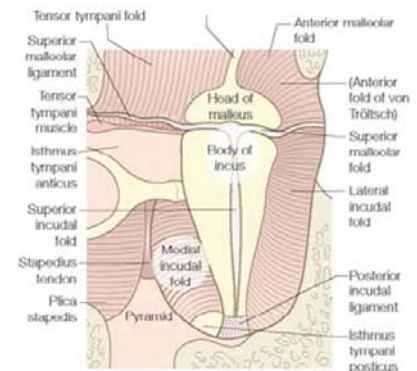
- **Mesotympanum communicates with Attic via:**

1. Anterior Isthmus:

- Between Tensor Tympani tendon and Stapes.

2. Posterior Isthmus:

- Between Stapedius tendon and Pyramid, and Short Process of Incus.



- Any obstruction in the pathways of ventilation can cause Retraction pockets or Atelectasis of TM:
 - o **Obstruction of ET** → Total Atelectasis of TM.
 - o **Obstruction in Middle ear** → Retraction pocket in posterior part of Middle ear while Anterior part is ventilated.
 - o **Obstruction of Isthmi** → Attic Retraction pocket.
 - o **Obstruction at Aditus** → Cholesterol granuloma and collection of mucoid discharge in mastoid air cells, while Middle ear and Attic appear Normal.
- Principles of Management of Retraction pockets and Atelectasis of middle ear would entail Correction/repair of the irreversible pathologic processes and establishment of the ventilation.
- **Patulous Eustachian Tube:**
 - ET is abnormally patent.
 - Mainly idiopathic.
 - Acquired:
 - o Scarring post Adenoidectomy.
 - o Rapid weight loss.
 - o Pregnancy (Third trimester).
 - o Multiple Sclerosis.
- **Signs and Symptoms:**
 - Distorted Autophony (Abnormal perception of one's own breath and voice sounds – **most common**)
 - o Echoing occasionally severe enough to interfere with speech production
 - Fluctuating Aural fullness.
 - Roaring Tinnitus synchronous with nasal respiration.
 - Audible respiratory sounds.
 - Synchronous TM movement with Respiration can be seen on otoscopy.
 - Symptoms improve when Supine.
- Self-limiting and does not require treatment.
- Weight gain, oral administration of potassium iodide is helpful but some long-standing cases may require cauterisation of the tubes or insertion of a grommet.